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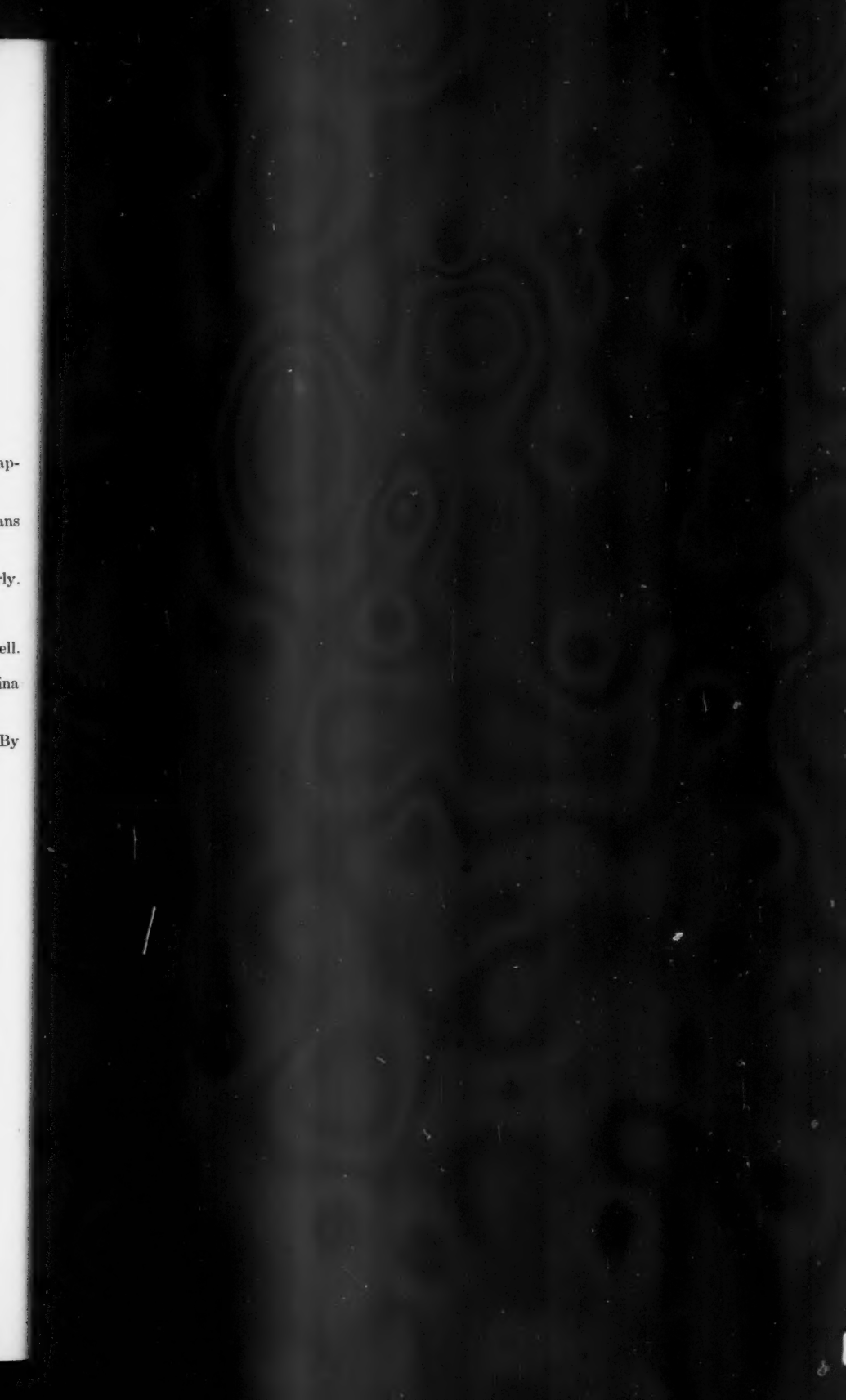

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Babol
TRANSIRANIAN RAILWAY
Ashraf
RUD
TALAR RUD
Amul
Shahi
ELBURZ
Damghan
Mt. DEMAVEND
Firuzkuh
Semnan
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KUH-I-GITCHA
KUH-I-GUGIRD
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Bujnurd
Shirwan
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Shahrud
Sabzawar
Turut
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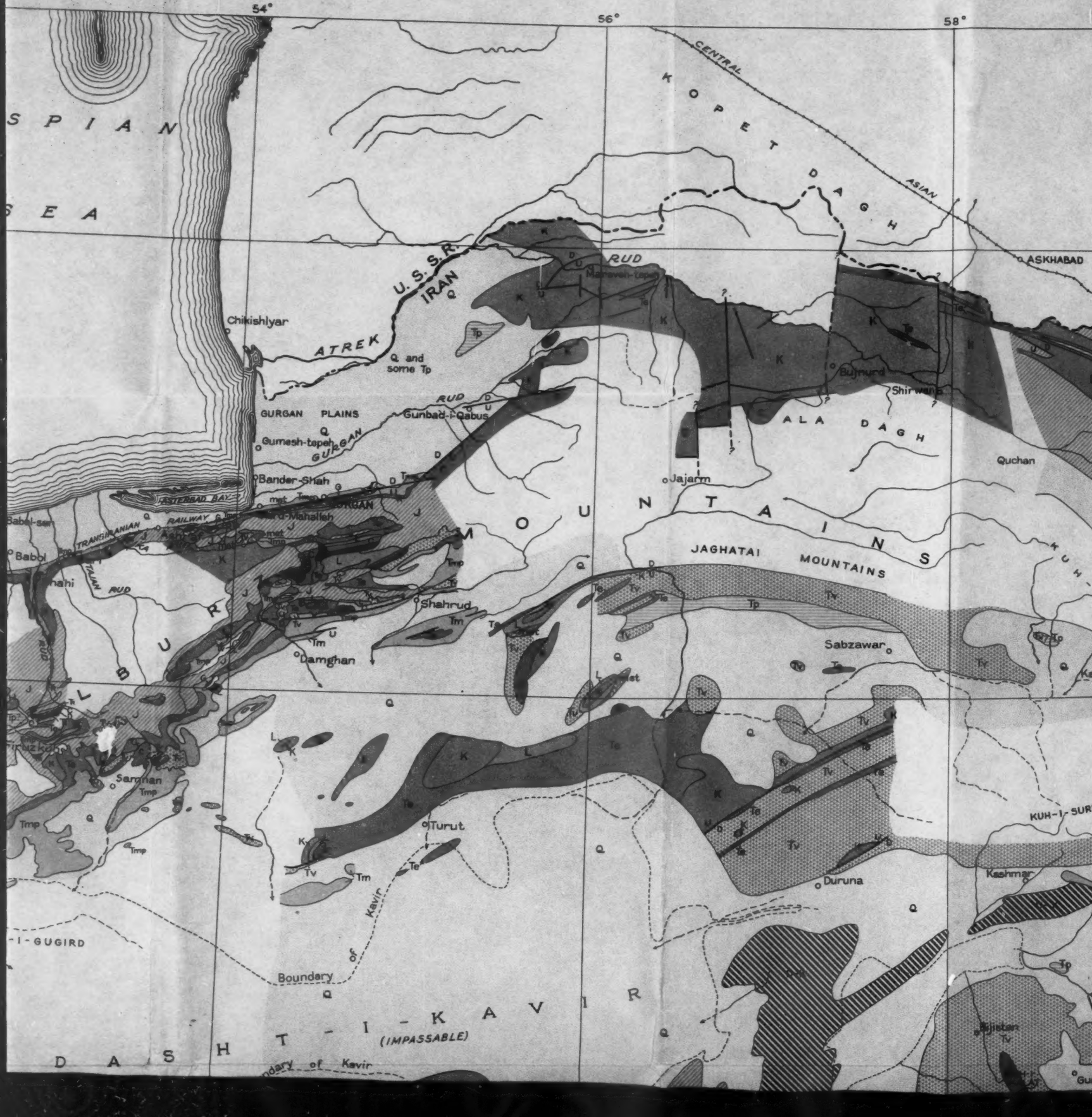
Kavir
(IMPASSABLE)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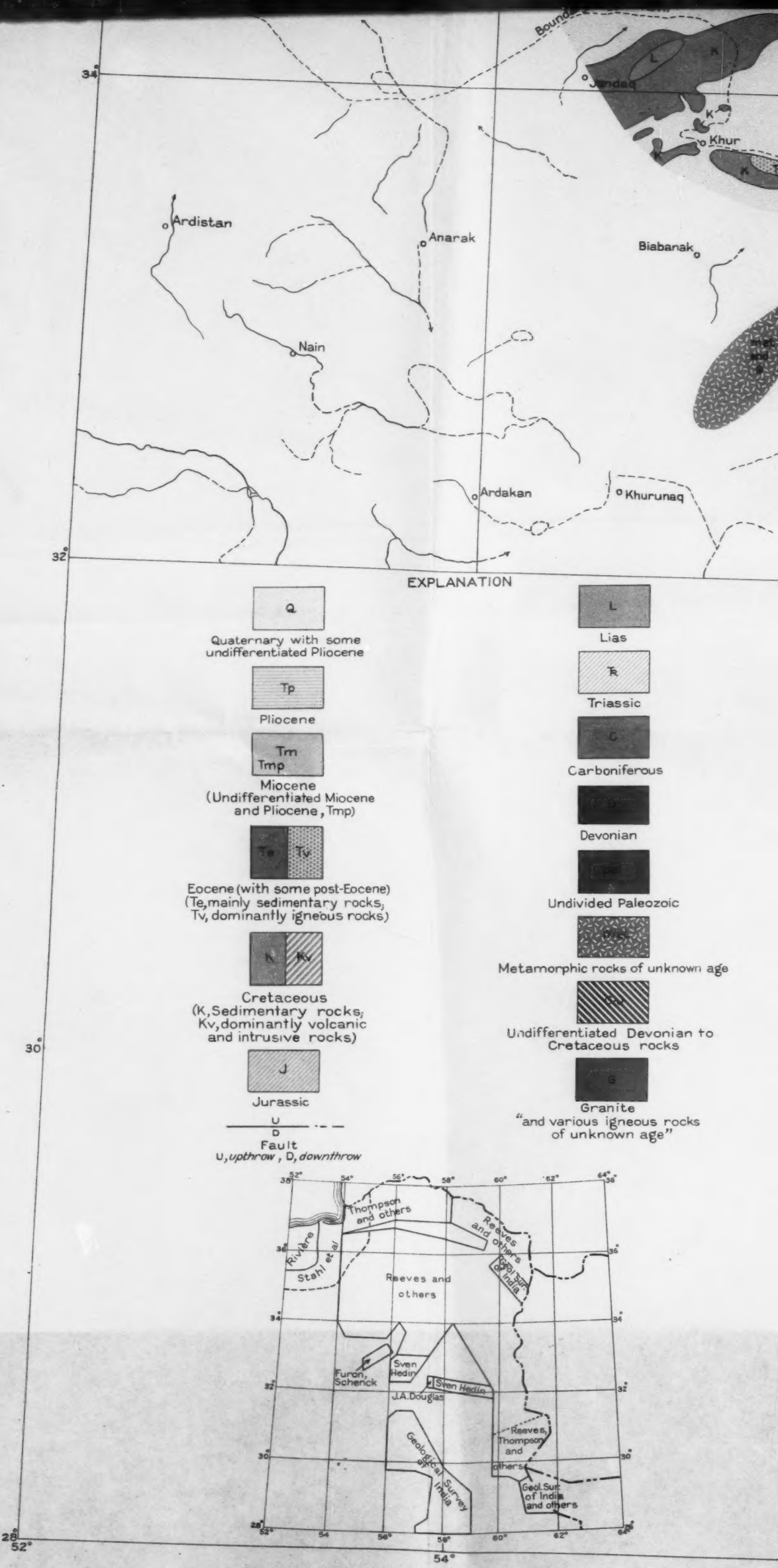
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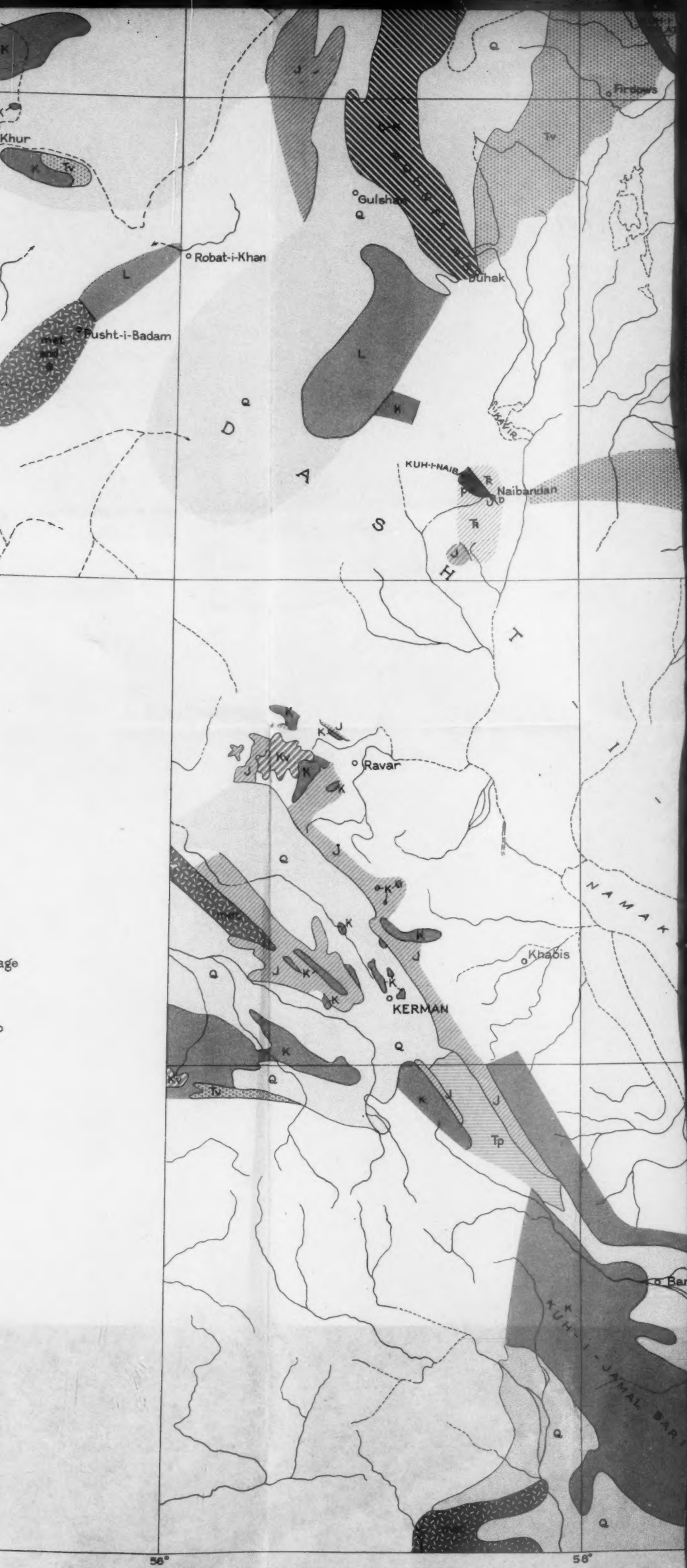
Khur
EXPLANATION
Q
Quaternary with some undifferentiated Pliocene
Tp
Pliocene
Tm
Tmp
Miocene
(Undifferentiated Miocene and Pliocene, Tmp)
Te
Tv
Eocene (with some post-Eocene)
(Te, mainly sedimentary rocks;
Tv, dominantly igneous rocks)
K
Kv
Cretaceous
(K, Sedimentary rocks;
Kv, dominantly volcanic and intrusive rocks)
J
Jurassic
U
D
Fault
U, upthrow, D, downthrow
L
Lias
TR
Triassic
C
Carboniferous
D
Devonian
Pz
Undivided Paleozoic
D-Cr
Metamorphic rocks of unknown age
D-Cr
Undifferentiated Devonian to Cretaceous rocks
G
Granite
"and various igneous rocks of unknown age"
Thompson and others
Reeves and others
Geol. Surv. of India
Riviere
Stahl et al
Reeves and others
Furon, Schenck
Sven Hedin
J.A. Douglas
Reeves, Thompson and others
Geol. Surv. of India and others

GE



GEOLOGIC MAP OF PART OF EASTE

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OF PART OF EASTERN IRAN

50 0 50 100 MILES

100 KILOMETERS

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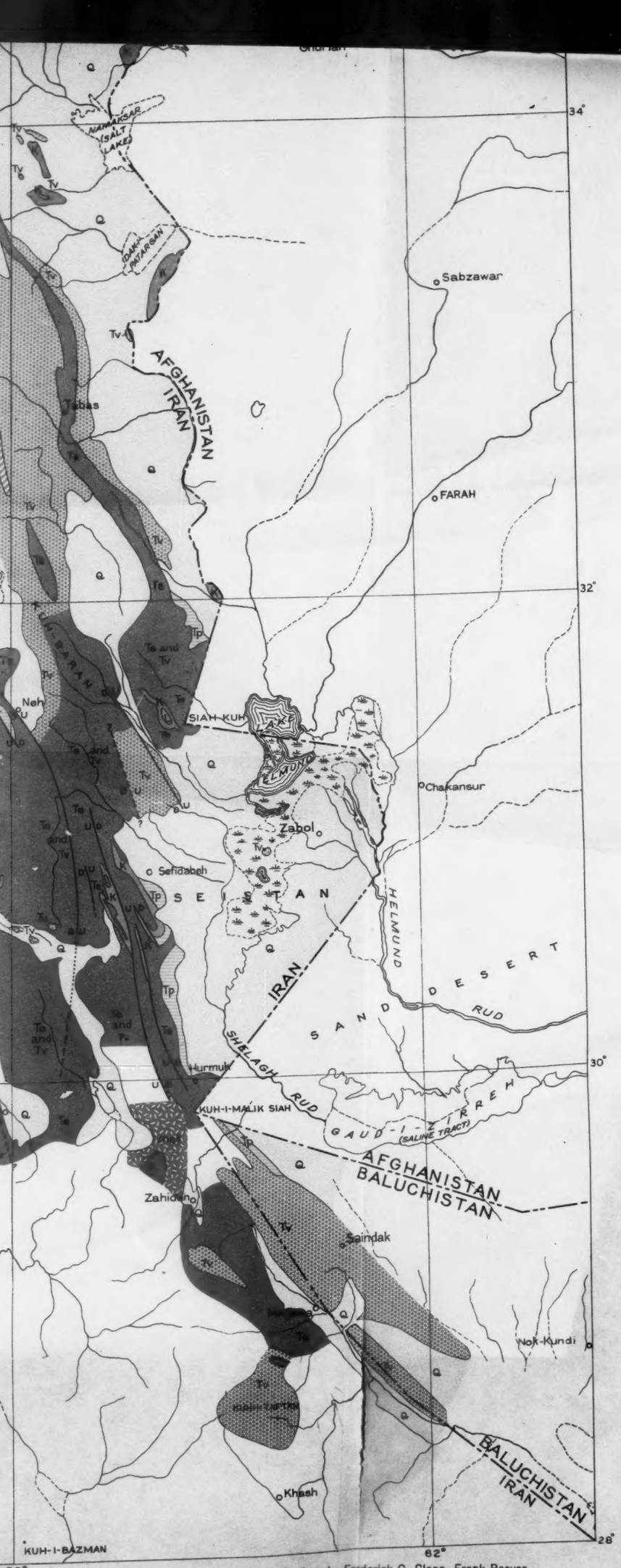

Geology by Frederick G. Clapp, Frank Reeves, H. G. Scherck, and L. S. Thompson, assisted by Khadji Afshar, B. F. Buie, E. Gardner Clapp, Henry Hotchkiss, and Walter Wilson, from data belonging to Amiranian Oil Co., 1937-38. Kerman region by Geological Survey of India, Nalbandan after J. A. Douglas.

Co-ordination by Frederick G. Clapp

Base from Survey of India maps

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GEOLOGY OF EASTERN IRAN

BY FREDERICK G. CLAPP

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ABSTRACT

The Iranian plateau is a triangular area bounded on the north by the Elburz mountain system and on the southwest by the Zagros, the intervening area being arid and having a number of interior basins with no outlet to the ocean. The trends of the bordering mountains and intra-desert areas are in general east-west or northwest-southeast, but north-south trending ranges also exist in central and eastern sections. The country has been brought to this condition by tectonic forces which have faulted and overthrust the bounding ranges and much of the interior and have step-faulted the rocks downward in parts of the east and north. The regional structure is therefore complicated but is intercepted by basins in which more moderate types of folding exist. That the plateau is still in process of elevation is evident from recurrent earthquakes.

The maximum composite thickness of the rocks aggregates nearly 100,000 feet. The formations range in age from possibly pre-Cambrian up to Recent, but the oldest positively known strata are Cambrian. Major unconformities exist, of which that at the base of the Cretaceous is the most intensive and far-reaching, but pre-Triassic, pre-Eocene, pre-Pliocene, and post-Pliocene unconformities are also important.

Cambrian rocks, although known in a single locality in south-central Iran and not at all farther east and north, are 7000 feet thick in southwestern Iran. Ordovician and Silurian rocks are unknown. Devonian strata, mapped in a few places in the Elburz Mountains and central Iran, have a maximum known composite thickness of about 2000 feet. Carboniferous and Permian are likewise present in considerable areas of the Elburz and central Iran; these systems aggregate about 5000 feet thick in places. Triassic rocks are less common but are known to be over 2000 feet in a few places in central-eastern and northern Iran; Jurassic formations aggregate possibly 10,000 feet in the northeast and occur with lesser thickness in wide areas from south-central Iran to the northern frontier and from the Afghan border to central Iran. Cretaceous rocks amount to over 13,000 feet in extreme north-eastern Iran; they outcrop over wide areas north of the Elburz and numerous areas in central Iran. Tertiary rocks are of great thickness, aggregating in one place or another over 40,000 feet, of which more than half the column is locally Miocene. Eocene rocks, locally over 8000 feet thick, are known north of the Elburz and, in a number of interior basins south of these mountains; and cover wide areas in the East. Quaternary deposits consist mainly of outwash gravels but also include loess in the extreme north and deposits of alluvial nature in many places.

INTRODUCTION

Although western Iran has been the subject of geologic publications for a century, the eastern part of that country usually has been considered too remote to deserve attention. It remained for the geologists of Amiranian Oil Company to make reconnaissance maps from which the accompanying geologic map (Pl. 1) has been compiled. The present

writer, whose studies commenced in 1927 and were extended in 1933, had charge of expeditions in 1937 and 1938 and participated in them, at the same time supervising and coordinating work done by several field geologists. It is a source of regret to the author that his administrative and supervisory activities prevented him from personally carrying out more intensive field studies along certain lines of scientific interest.

The present record has been prepared with collaboration by Dr. Hubert G. Schenck, Lester H. Thompson, Dr. Frank Reeves, and others. Credit is due to these men who traversed mountains and deserts alike with exceeding diligence and submitted reports which form a basis for the conclusions reached herein. Doctor Reeves, assisted at various times by Bennett Frank Buie and Walter P. Wilson, was assigned the extreme northeastern and north-central regions and rapidly mapped vast areas. Messrs. Thompson, Henry Hotchkiss, and Khadgi Afshar covered much of the North and a considerable area in the extreme Southeast. The small map inset on Plate 1 designates the areas in which certain geologists are mainly responsible for the mapping. The author must assume responsibility for an attempt to coordinate the geology on the large map.

Throughout the field studies of 1937 and 1938 Professor Schenck was in charge of the paleontologic work, participating in field reconnaissances and conducting office paleontologic work insofar as this was possible inside Iran; he was likewise of great assistance in interpreting stratigraphy. The author is consequently indebted to him for a majority of the determinations of samples collected and for assignment of ages. Fossil interpretations and determinations by Prof. S. W. Muller, who was in Europe at the time, have added materially to our knowledge. The following specialists were informally consulted by Doctor Schenck and contributed confirmation as to the identity of certain species: Louis Castex, L. R. Cox, Col. L. M. Davies, F. Demanet, W. O. Dietrich, H. L. Hawkins, A. Jeannet, A. Myra Keen, Helen Muir-Wood, L. F. Spath, and H. Dighton Thomas. The tables of fossils are compilations made by the author from existing literature and the Company's paleontologic reports. Special thanks are due to Professors Schenck and Muller and Dr. A. Myra Keen for criticizing and correcting this manuscript, especially its paleontologic portions in the details of which the author was not personally versed. Professor Schenck has suggested calling attention to the fact that many of the fossil names used in this paper are those of early publications and that others are provisional identifications and hence subject to correction. No exhaustive attempt is here made to modernize every name. He has also pointed out that special

papers are being prepared for publication regarding many of the fossils, in which adequate systematic discussions will be incorporated.

The President and Board of Directors of Amiranian Oil Company (now liquidated) were generous in granting permission to publish. The Government and people of Iran were unceasingly helpful in their attitude toward this undertaking, and the facilities afforded by them have made the work possible. For all of the above the author tenders his thanks and appreciation.

Since the purpose of the present exposition is to place some of the available information on record for the use of future investigators, the paper includes details which might be omitted from a discussion having more specific objectives. Although every effort is made to allot proper credit for data and results, the author himself is usually responsible for the statements made in cases where other persons or sources are not mentioned.

In any geographic discussion of the Orient the question of correct transliteration of place names is of prime importance, since these must be located by future scientific investigators. Renderings from the Persian language may have any one of several spellings, according to the nationality and linguistic background of the person interpreting them, and accuracy as regards all of the names can hardly be expected. The spelling follows the usage of the following authorities in the order of precedence mentioned:

(1) United States Geographic Board: First report on foreign geographic names, 1932, 113 pages.
(2) Permanent Committee on Geographical Names for British official use:
  (a) *First list of names in Persia (South)*, June, 1928, 16 pages.
  (b) *Second list of names in Persia (North)*, August, 1929, 11 pages.
(3) Maps of the Indian Survey series (1:1,000,000).
(4) Spellings found in geologic literature in the English, French, and German languages.
(5) Spellings adopted by field geologists from local pronunciation in cases where written names are unavailable.

Longitudes mentioned herein are east from Greenwich.

PREVIOUS WORK

A number of papers on the geology of Iran appeared about 90 years ago. In 1850 the Société Géologique de France published an account by Viquesnel of the journeys and extensive collections made by Monsieur Hommaire de Hell in eastern Mazandaran and the Elburz Mountains, the fossils being determined by De Verneuil. In 1853 Grewingk's geologic and orographic work appeared; this is a digest of notes and collections made by Dr. F. Bühse and Lt.-Col. Woskoiboinikow from the Caspian Provinces as far east as Shahrud. Some prior memoranda had been published on northern Iran in 1846.

However, the earliest comprehensive treatise on Iranian geology was that by Loftus (1855, p. 247-344) of the Turkish-Persian Boundary Commission. Table 1 is the resulting geologic column of that date.

Loftus' geologic map extended from Lake Van (in Turkey) south-

TABLE 1.—*Geologic column reported by Loftus*

"Period"	"Series"
Recent	3. Alluvium 2. Lacustrine deposits 1. Limestone gravel
Tertiary	2. "Gypsiferous series" (including all Tertiary deposits above "Nummulitic limestone") 1. "Nummulitic series"
Secondary	2. "Upper Secondary" or "Cretaceous series" 1. "Lower Secondary series"
Paleozoic	
Metamorphic rocks	
Plutonic rocks	2. Granites 1. Trappean rocks

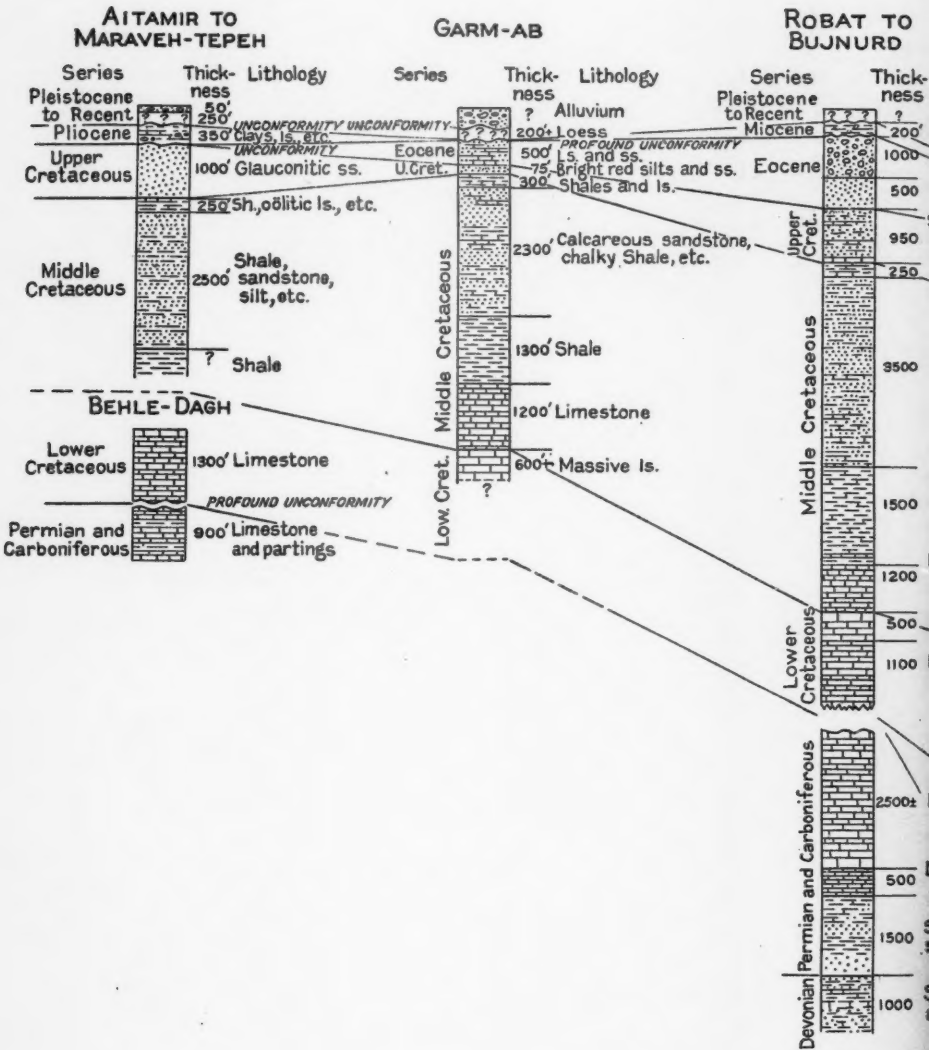
east to Shiraz and from Isfahan and Persepolis to the Persian Gulf. His descriptions and geologic sections of southwest Iran are classic.

Following the earliest studies two decades elapsed before Blanford's work for the eastern Persian Boundary Commission commenced in 1870 (Blanford, 1876) and continued during 3 years of arduous reconnaissance from British Baluchistan [1] as far northwest as the Elburz Mountains. Many of the early geologic explorations in Iran were sponsored by the Geological Survey of India. Griesbach (1881, p. 95) made extensive reconnaissances in Afghanistan a few years later and published a comprehensive section (Table 2) for northeast Khurasan.

The work of Vredenburg (1901) was of great importance along the British frontier and to the west as far as Kuh-i-Taftan. His geologic column is summarized in Table 3.

In 1905 and 1906 a difficult journey was made by Hedin (1918) from Tehran along the south edge of the Dasht-i-Kavir, across the desert to Turut and back to Khur, thence to Gulshan (formerly Tabas), Naibandan, Neh, and the deserts of southern Afghanistan. Subsequently Hedin's

[1] Throughout this paper the word "British" is prefixed to the territory commonly included in "Baluchistan," in order to distinguish between that country and the former Iranian Province of Baluchistan, now commonly spoken of as "Makran." The adjective "British" is used by itself in places to describe the frontier of British Baluchistan.



GEOLOGICAL COLUMNAR SECTIONS FROM WE

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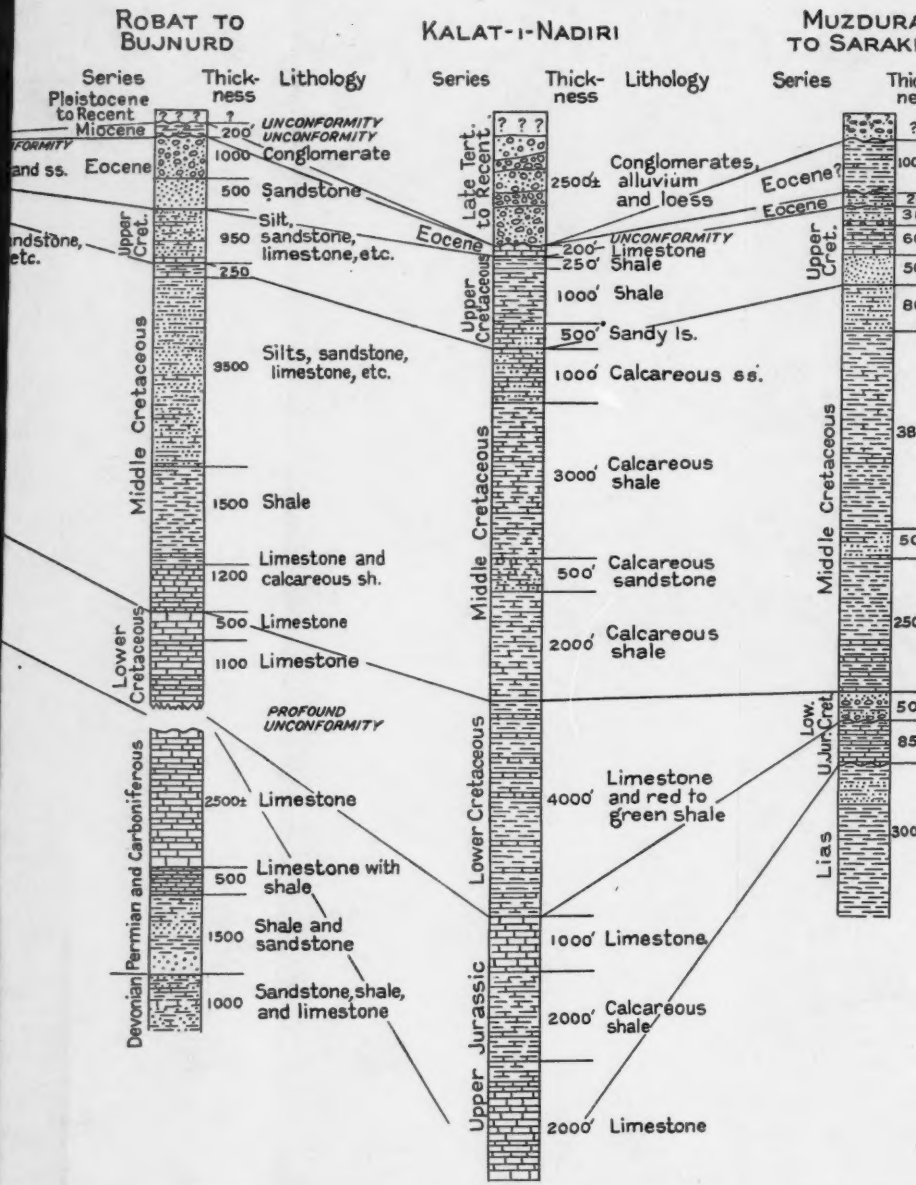

AR SECTIONS FROM WEST TO EAST ACROSS NORTHEAST IRAN

tern three sections by Thompson and others; eastern two sections by Reeves and others.

MUZDURAN
D SARAKHS

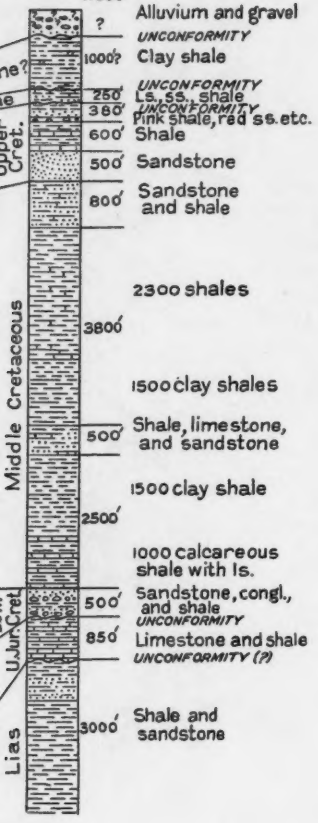

TABLE 2.—*Geologic column reported by Griesbach*

Period	Series	Description	Localities
Recent		Blown sand, alluvial deposits, and salt-pans	
Tertiary	Upper Pliocene	Loess	Lower Jam Valley, Nishapur plain, etc.
	Lower Miocene	Sandstone with *Ostrea multicostata* Deshayes	Near Khaf
	Eocene	Nummulitic limestones with rhyolites	Between Nishapur and Madan
Cretaceous	Upper Cretaceous	White chalk	Kalat-i-Nadiri and Zurabad
		Inoceramus beds	Zurabad
		Exogyra limestone	Takht-i-Gauzek near Pul-i-Khvatun, Kalat-i-Nadiri, etc.
	Middle Cretaceous	*Trigonia* beds and shell limestone of the Takht-i-Gauzek	Takht-i-Gauzek
		White plant-bearing sandstone	Kalat-i-Nadiri
	"Neocomian"	Red grits	Kat-i-Shamshir (S. W. of Meshed); Madan, Farimun, SE. of Meshed; Yaktan Range
Jurassic		Black shales with fragments of plants	Zurabad; Garmab (Kat-i-Shamshir range), west of Takht-i-Gauzek
		Limestones and shales with marine fossils	Gaukharchang Pass (Burj-i-Kalij Khan)
"Triassic and Permian"		Green shales	Yaktan Range and Dehrud Pass
Carboniferous	"Carboniferous"	*Productus* limestone	Yaktan Range, Dehrud Pass.
	"Subcarboniferous"		Dehrud Pass

scientific results were described at some length (Hedin, 1927, p. 381-532). About the same date appeared the geologic volumes of a monumental work by De Morgan (1905a; 1905b). Paleontologic chapters by Cotteau, Gauthier, and Douvillé (largely sponsored by Douvillé), having excellent illustrations of numerous species, had already appeared in several sections dating from 1895 to 1904.

Information on eastern Iran came from many scattered sources. Among explorers of the first decade of the present century must be mentioned Col. Sir Henry McMahon (1906, p. 333-352) who remained in Seistan 2½ years and published much useful information on climate

TABLE 3.—*Geologic column reported by Vredenburg*

Period	Series	Description and locality
Recent	Alluvium Volcanics Travertine	Tuff and agglomerates of Kuh-i-Taftan
	Siwalik	Coarse gravel deposits near northwest corner of British Baluchistan
	Khirthar	Agglomerates and limestones at Saindek (British Baluchistan)
	Ranikot	Shales of Kuh-i-Malik Siah
Cretaceous	Flysch	Tuffs, agglomerates, and various marine beds
	Hippuritic limestone	
Igneous intrusions		

and regional conditions. McMahon (1897, p. 297-309) had previously travelled in Seistan and presented petrologic and other useful information. The first work of Pilgrim, pertaining to Iran, appeared in 1908, but his mapping extended only half way from the coast to the cities of Yezd and Kerman. Much valuable geologic work was done throughout central and northwest Iran by Stahl, while he was a resident in Iran, and his final map was published in 1911. Sir Percy Sykes (1897; 1912) explored the country along various traverses. The work of Tipper (1921) was done, in 1912 and 1913, in an area which is now western Makran, and this geologist was able to distinguish the formations named in Table 4.

Journeys were made by Gen. Oskar von Niedermayer in 1912 to 1916, resulting in a description (1920) of the tectonics, morphology, hydrology, and climate of eastern Iran. This was followed by a contribution by Krumbeck (1922) in which the fossil forms of (1) The Elburz region, (2) Khurasan, and (3) Central and Southwest Iran were compared in tabular form. A stratigraphic column, compiled by Krumbeck, is summarized in Table 5.

In the second decade of the century valuable work was done by Pilgrim (1924, p. 3-4); his geologic column is outlined in Table 6 as

being of historical interest with reference to correlations between eastern and southwestern Iran.

Tipper and Pilgrim differed from Stahl in many particulars, but

TABLE 4.—*Geologic column reported by Tipper*

Period	Series	Description
Pleistocene and Recent		Newer and older alluvium; Recent lavas
	Unconformity	
Pliocene	Siwalik ?	Boulder beds, gravels, and shales (Unfossiliferous)
	Unconformity	
Miocene	Makran (Upper Hinglaj stage)	Soft, greenish, calcareous sandstones with nodular bands, and harder sandstones
	Unconformity	
Eocene and Oligocene		Sandstones and slates
	Unconformity	
Cretaceous	Upper Cretaceous volcanic series	Fine-grained tuffs (rhyolitic), and basic lava flows, agglomerates and igneous dikes
	"Hippuritic limestones"	Limestones and sandstones
	Unconformity	
Jurassic	"Plant-bearing series"	Highly colored shales and limestones
Lias		Limestones and vari-colored shales
	Unconformity	
Carboniferous		Thin-bedded, dark crinoidal limestones
Metamorphic rocks of unknown age		Crushed serpentines, schists, phyllites, crystalline limestone

all explorers agreed in leaving the map blank northeast of Yezd and Ravar. The rocks of the "Hatát," "Oman," and "Hormuz" series were not specifically recognized in eastern Iran, and, moreover, a discussion of the problem of the "Hormuz series" is not pertinent to east-Iranian geology. Many questions which were vaguely understood in Pilgrim's day are now being answered, and a portion at least of the

TABLE 5.—*Geologic column according to Krumbeck*

Era	Subdivisions	Recognized distribution
Quaternary	Diluvium	1, 2
Tertiary	Pliocene	1
	Miocene	1 ?, 3
	Oligocene	
	Eocene	3
Cretaceous	Upper Senonian	1
	Lower Senonian	2
	Turonian	1
	Cenomanian	1, 2, 3
	Gault and Albian	2
	Aptian	3
	Barremian	2, 3
	Hauterivian	1
Upper Jurassic	Kimmeridgian	2
	Tithonian	2
	Oxfordian	2
Middle Jurassic		1
Lower Jurassic	Lias	1
Triassic	Rhaetian	1
	Norian	3
	Carnian	2
	Ladinian	1, 2
	Anisian	1
Permian		1
Carboniferous	Visean	1
	Tournasian	1
	Lower Carboniferous	1
Devonian	Upper Devonian	1, 2, 3
	Middle or Lower Devonian	2 ?, 3 ?
Middle or Lower Devonian or Silurian		2 ?

1=Elburz region. 2=Khurasan. 3=Central and Southwest Iran.

"Hormuz series" can be safely assigned to Cambrian age. Again, the "Hippuritic limestone" of Vredenburg and Tipper is undoubtedly identical stratigraphically with certain Cretaceous limestones of eastern Iran,

TABLE 6.—*Geologic column reported by Pilgrim*

Period	Series	Description
Pleistocene		Shelly conglomerates and reefs of the littoral; old river deposits; foraminiferal oölite (Miliolite)
Pliocene	Bakhtiari	Fluviatile grits and conglomerates
	Khan-i-Surkh	Lavas and ash beds
Miocene	Fars	Sandstones, clays, and limestones with interbedded and basal gypsum beds
Oligocene	Khamir	Limestones, sandstones, and grits
Eocene	Ginau	Limestones and shales
	Zindan	Sandstones, clays, and shales with lenticles of limestones
	Panj ?	Intrusive diorites
Upper Cretaceous	Semail	Basic intrusives; serpentines
	Dukhtar	Shales and limestones; volcanic agglomerates and interbedded lava flows
Middle Cretaceous	"Hippuritic limestone"	
Lias		Plant-bearing series
?	Hormuz	Salt
		Dolomitic limestones, volcanic agglomerates, and sandstones, with interbedded lava flows
		Intrusive rocks
"Permo-Carboniferous to Triassic"	Oman	Limestones, slaty shales, and quartzites
Archean ?	Hatát	Schists, phyllites, quartzites

but eastern and northern limestones of this age are more diverse in character than those reported in early reports on the Southwest. Likewise, although Pilgrim's intrusive rocks may be contemporaneous with certain dike rocks of eastern Iran, his "Panj" and "Semail" areas have not been differentiated in the East. A few remarks on probable correlations of the "Zindan," "Ginau," and "Khamir series" with east Iranian Eocene and Oligocene strata are made in the present paper. The Fars series of the Persian Gulf undoubtedly extends into eastern Iran,

but its upper and lower limits may not be identical from place to place. The same may be said of the "Bakhtiari series" of the Southwest. Consequently, although Pilgrim's area scarcely touches that of the present study, many of his problems are interwoven with those considered in this paper.

Among the older explorers was De Morgan (1905), whose fossils were determined by Douvillé (1901). An excellent résumé of the recognized time subdivisions was given by Douvillé (1904, p. 552-553). Among recent contributions, Rivière's studies in the central Elburz are paramount. Paleontologic work by the Indian Survey has been helpful in making correlations into eastern Iran.

In 1924 another work appeared which greatly elucidates the geology of western Iran and helps toward an understanding of the stratigraphy of all sections of the country. This contribution is Richardson's paper on southwestern Iran—a subject previously covered in a preliminary way by Busk and Mayo (1918). Studies of the Triassic in the vicinity of Naibandan were published by Douglas (1929), based on collections made by Messrs. R. C. Jennings and Washington Gray on behalf of Anglo-Iranian Oil Company. In the same year appeared *The Structure of Asia* under editorship of J. W. Gregory; this contains a long chapter pertinent to southwest Iran by De Böckh, Lees, and Richardson and compiles many essential facts with reference to the stratigraphy and tectonics. Furon (1936-1938) made journeys of observation in eastern Iran. From time to time other helpful papers by Stahl and Rivière have appeared.

PHYSIOGRAPHY

To obtain structural perspectives the region under consideration should be studied in connection with the topography of Iran as a whole. Altitudes range from 84 feet below ocean level on the Caspian Sea to the crest of Mount Demavend, variously reported but now generally considered about 18,549 feet high. All of Iran is a plateau (Fig. 1) except (1) The Mesopotamian belt which fronts on the Persian Gulf and touches Iraq in the west, (2) lowlands which surround the Caspian Sea, extending northeast and touching the north frontier of Khurasan Province, and (3) valleys of the Hari Rud and Helmund rivers on the east frontier. The breadth of the plateau ranges from a minimum of approximately 300 miles (about 500 km.), along the approximate route of the Trans-iranian Railway, to a maximum of 700 miles (about 1100 km.) on a line from Bandar 'Abbas on the Persian Gulf northeast to and beyond Meshed. This plateau extends with little interruption for about 2300 miles (3700 km.) from the Sea of Marmora across Turkey, Iran, and

Afghanistan to the Indus Valley. The seas in which Iranian rocks were deposited occupied a basin of depression and subsequent epeirogenic activity called by Suess (1904, vol. 3, p. 19) the Tethys; this basin

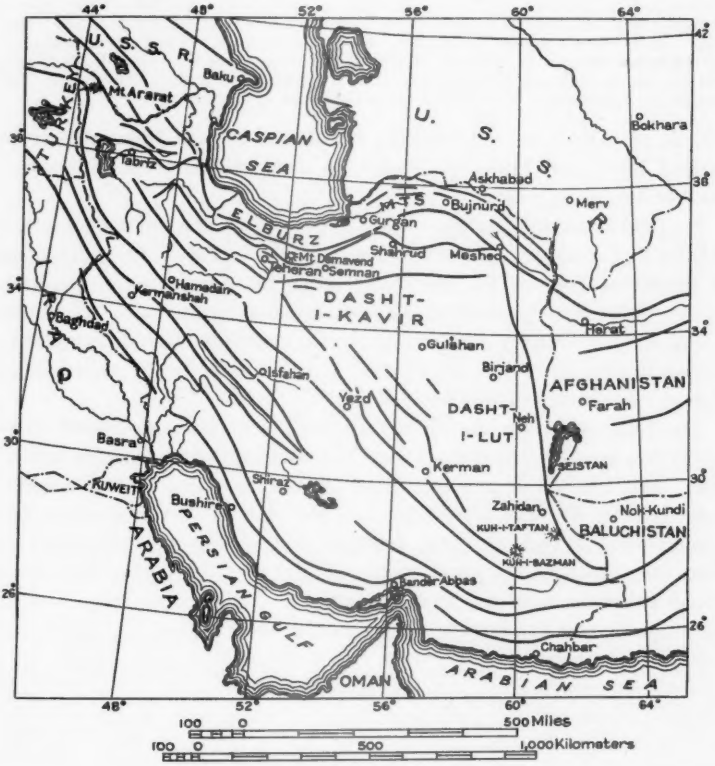

FIGURE 1.—*Principal trend lines of Iran*
(After Stahl and others.)

lay between the old continent of Gondwanaland to the south and that of Angaraland to the northeast.

Bounding the Iranian plateau on the north, from Mount Ararat eastward, is the Elburz Mountain system (Pl. 3), which breaks up toward the east into subsidiary ranges—the Ala Dagh, Jaghatai Mountains, Kuh-i-Hazar Masjid, Kuh-i-Binalud, Kuh-i-Dizak, and others (Pl. 1). According to Suess (1904, vol. 3, p. 289) "the Albourz is an arc of central Asiatic type." He evidently interpreted the Elburz axis as

dying out in eastern Iran, for he connects the Kopet Dagh with the Paropamisus range of Afghanistan in the following words (Suess, 1904, vol. 1, p. 490):

"but as it [the Paropamisus] proceeds with an undeviating north-westerly direction through the Kurendagh to the Caucasus, it completely leaves the region of the Iranian folds. In its place a second arc appears, which corresponds to the western part of the outer Iranian chains; the northern border of this at the same time bounds the Caspian Sea, but, as we shall see directly, also shows a tendency to prolong the branch, which runs to the northward. This second arc is the range of the Albourz."

The Kopet Dagh, on the northern frontier of eastern Iran, already described by Davis (1905, p. 46-47), is geographically an extension of the Caucasian alignment.

Another mountain system—the Zagros—forms the southwest side of the Iranian plateau and part of an arc which extends from Kurdistan in northwest Iran as far southeasterly as the mountains of northwest India. Near the east end of the southern highlands stand two notable peaks of late Tertiary and Recent volcanic origin—Kuh-i-Bazman and Kuh-i-Taftan; the latter, 12,850 feet in altitude, is locally called Chehel Tan or "Mountain of the Forty Beings."

The region between the Elburz on the North and the Zagros on the Southwest is of plateau type throughout, although parts of it are actually low. Salt lakes and dry salt pans form a nucleus of several central bolsons (Fig. 4). The longest river is the Hari Rud, which enters from Afghanistan, bounds the east frontier of Iran for some distance, and then loses itself in the great plains of Merv to the north. The Atrek, which coincides with the frontier north of Gurgan Province (formerly Asterabad), and the smaller Gurgan enter the Caspian through central Gurgan province. Few parts of the world evince such a paucity of streams as eastern Iran, and few countries are so arid. In view of the climatic disadvantages overcome during thousands of years, the existence and progress of the Iranian people are a tribute to their endurance and hopes for the future.

Iranian plateau altitudes are diverse, for, although many are 5000 and 10,000 feet, with summits of 11,000 and 18,000 feet, the vast basins of the Dasht-i-Kavir (Great Salt Desert) and Dasht-i-Lut (Great Sandy Desert) descend roughly to 3000 and 1000 feet respectively above sea level throughout expanses of 100 to 200 miles (150 to 300 km.). The central highlands surrounding Gulshan (formerly Tabas), Bijistan, and Naibandan, and separating the Dasht-i-Lut from the Dasht-i-Kavir, attain altitudes of 4000 to 8000 feet. Uplands between Bafq and Kerman and thence to Bampur, in south-central Iran, stand similarly high. The Zahidan highlands of the southeast are 5000 to 7000 feet high, ter-

minating eastwardly in Kuh-i-Malik Siah, 5390 feet in altitude, at the common corner of Iran, Afghanistan, and British Baluchistan.

Huntington (1905, p. 219-317) named the continuous series of eastern lowlands, from the Soviet frontier southward, the "Serakhs," "Zuhra-

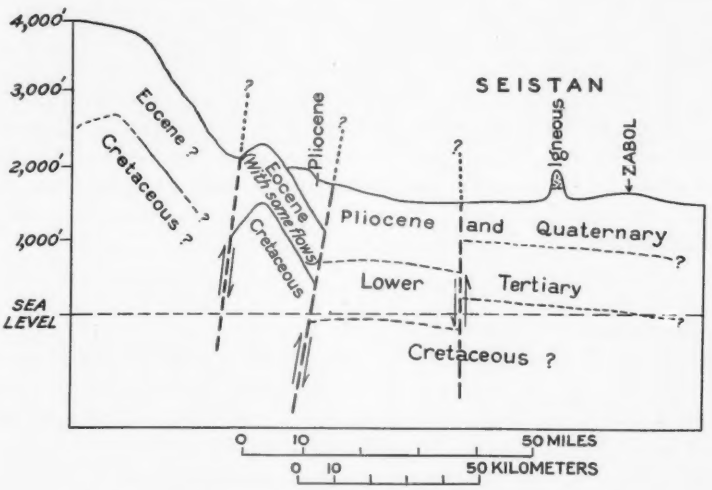

FIGURE 2.—*Hypothetical section across western Seistan*
By Amiranian Oil Company; according to hypothesis of the author.

bad," "Jam," "Namakzar," and "Seistan" depressions. Such plateau lowlands, generally occupied by salt lakes and salt pans, are interesting and, in some cases, structurally important. The principal depressions are the basins of Darya-yi-Namak in the Dasht-i-Kavir northeast of Qum, the Namakzar in the Dasht-i-Lut northeast of Kerman, and Daryacheh-i-Namakzar on the boundary of Iran and Afghanistan. Farther south on the same frontier lies the Seistan depression in which the Hamun-i-Helmund is formed by the Helmund and smaller Afghan rivers. This Lake Helmund occupies the west end of a depression 180 miles wide and 320 miles long, extending into the central deserts of extreme southern Afghanistan. At certain times the Shelagh River flows out of Lake Helmund and feeds the Gaud-i-Zirrah—a salt depression in southwest Afghanistan. Thus, although the Gaud-i-Zirrah is a great salt flat, sometimes carrying in its center a lake of concentrated brine, Lake Helmund and its confluents are kept fresh by flushing in times of extreme

flood. Yet the time may soon come when these waters will be salty, for McMahon (1897, p. 41) says, referring to the Gaud-i-Zirrah, that

"the last time it received any water from the Helmund is, as far as I can ascertain, as long ago as 1880, *i. e.*, seventeen years ago."

Another extraneous depression is the Hamun-i-Mashkel, in the west end of British Baluchistan. All of these sunken portions of the plateau owe their origin to unequal elevation of the surrounding highlands or relative depression of the lowlands, in part due to faulting. The divergent trends, between the Elburz on the north and the Zagros on the southwest, form a vast, barren, triangular central region in which the important cities of Tehran, Meshed, Isfahan, Yedz, Kerman, and Zahidan are situated. Some of the less known places, such as Gurgan (in the north) and Zabol (formerly Nosratabad) in the southeast, lie in more fertile lowlands on the north and east.

TECTONICS AND REGIONAL STRUCTURE

The prevailing trend of the bounding mountain systems (Fig. 1) of eastern Iran is largely dependent on the regional structure. The Elburz of Iran and the Hindu Kush of Afghanistan (De Cizancourt, 1937) possess several common characteristics. These ranges trend east and have a single principal axis, bordered by outlying ranges of parallel to somewhat divergent trend as far north as the Turkoman Plains. The Elburz system, if the term be broadened to include the Kopet Dagh on the Turkoman frontier, forms part of the Alpine-Caucasian-Himalayan barrier which affects the climate of both Europe and Asia.

The Elburz ranges separate the central plateaus from the northern lowlands (Pl. 3). Any divergent trends of outlying ranges, as well as the northwest-trending mountains in northwest, southwest, and southeast Iran, are in contradistinction to the east-west alignment. In the northern regions, north of the main Elburz axis, and in Afghanistan, the ranges are arranged en echelon. The same is true of numerous anticlines, domes, longitudinal faults, and overthrusts of which they are composed. Thus the ranges of northeast Khurasan form alternating anticlines and synclines, none of which is persistent but all of which are oriented in an east-southeast direction.

Although the east-southeast system of folding predominates in southwestern Iran the normal strike throughout the eastern belt, from Bijistan and Gunabad south to Zahidan, varies from north-south near the Afghan frontier to N. 45° W. between Gulshan and Yezd, and the structures in the intra-desert areas as far west as Isfahan have approximately this average trend. Anticlines in the Khur area strike approximately N. 55° E.

FIGURE 1. LOOKING NORTH
Across barren outwash gravels to south face of Mt. Tochal in Elburz Mountains, north of Tehran.

FIGURE 2. LOOKING SOUTH
From fertile Gurgan plains near Kurd Mahalleh to Elburz Mountains obscured by cloud.

FIGURE 3. INTERMONTANE VALLEY
In Elburz system; the Jaja Rud between Tehran and Shamshak, Tehran province.

FIGURE 1. FAULTED MARINE PLIOCENE SEDIMENTS AND LOESS
Northeast Gurgan province.

FIGURE 2. FAULT IN "GREEN SERIES" (PROBABLY EOCENE)
Near Ferahzad, northwest of Tehran.

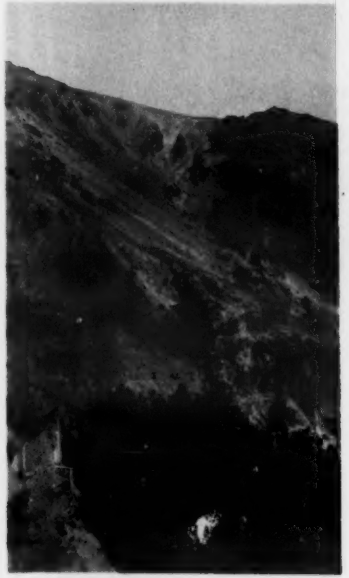

FIGURE 3. FAULT IN "GREEN SERIES" (PROBABLY EOCENE)
Near Pasgaleh north of Tehran.

EXAMPLES OF FAULTS IN NORTHEAST IRAN

and evince prominent jointing, numerous faults, abundant veins, and some igneous and clastic dikes.

Another tectonic area is the Zahidan massif in the southeast (Pl. 1). Farther south, in extreme southeast Iran, the general southeasterly prolongation from the Zagros region takes a bend and gives place to an average east-west trend in the ranges of southeast Makran and western Baluchistan.

Suess' (1904, vol. 3, p. 289) hypothesis of the threefold tectonic division of Asia would include the Iranian plateau in the geosyncline between his two ancient continents. But Iranian genesis is more complex than this. Suess' view was set aside by Argand's (1924) hypothesis, which assumed that the regional structure was due to union and contortion of various elements in a hypothetical southward drifting of an ancient continent; this view was modified and explained by F. E. Suess (1929). Doubtless new theories will be evolved in the future as in the past.

The structure of most of the region is not simple. Although various ranges in northeast Khurasan outwardly resemble each other the most northern ones have mainly an asymmetrical structure, with southwest dips which are in places as low as 15 to 20 degrees, opposed on the north flank by vertically dipping beds. The crests are complicated by closed and open folds, recumbent anticlines, minor crumplings, and overthrusts. Step faulting and tilting are widespread. Nevertheless, in some parts of these mountains the folding is more moderate and more symmetrical than in others.

Farther west the broadest part of the Elburz system, in eastern Gurgan and northwest Khurasan is reported by Thompson [2] to evince widespread block faulting in which Paleozoic and Cretaceous rocks may lie against each other along certain alignments and against Cretaceous and Tertiary strata in others. Some of the longitudinal faults are overthrusts (Pl. 5, fig. 3) which appear to have pushed notable thicknesses of faulted and folded subjacent strata across more recent beds, forming true nappes of the Alpine type (Fig. 3). The direction of the overthrust movement in the east-central Elburz was from the north, in east-central Iran it was from the west, and in extreme southeast Iran from the South. Opposed to these positive elements is the Caspian Sea, which occupies a depression due to the faulting which is progressively of greater displacement outward from the mountains. In Mazandaran and Gurgan the positions of the principal east-west faults are evinced by prominent cliffs and scarps in rocks which range from Carboniferous

[2] Since geologists or other persons associated with the writer in the employ of Amiranian Oil Company must be mentioned frequently herein for the assignment of collection localities, references will be made by mentioning only the surnames of Khadji Afshar, Bennett Frank Buie, Henry Hotchkiss, Dr. S. W. Muller, Dr. Frank Reeves, Dr. Hubert G. Schenck, and Lester S. Thompson.

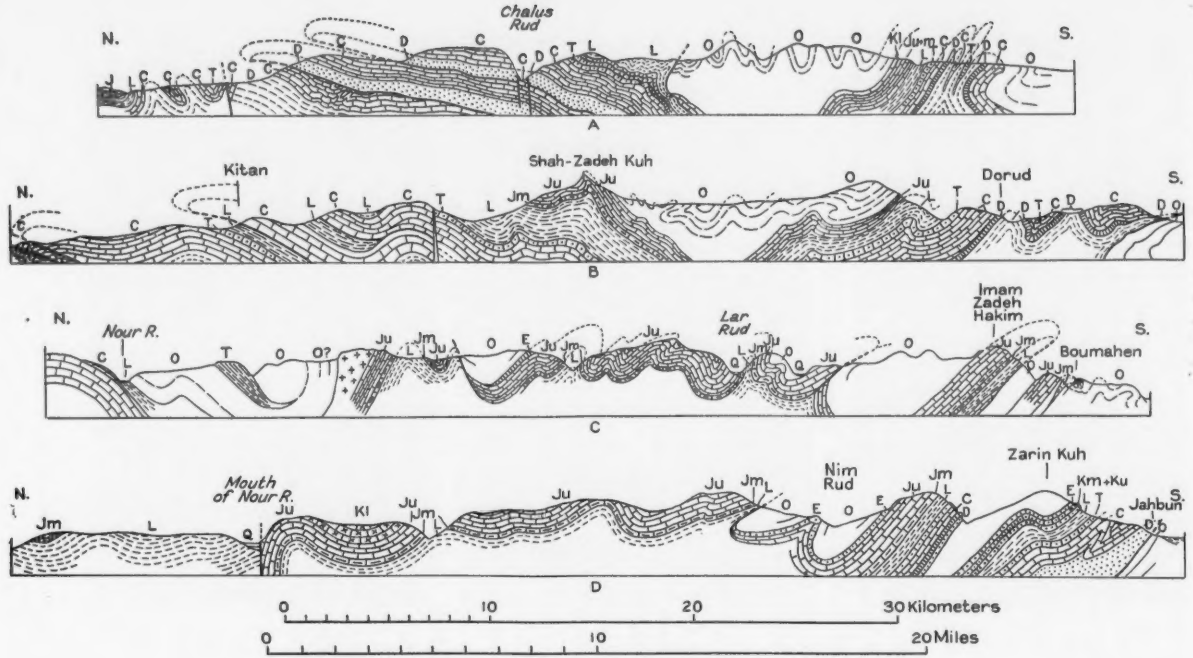

FIGURE 3.—*Cross sections in central Elburz Mountains*

After Rivière.

to Pleistocene in age. If the Caspian Sea does not occupy a graben it at least lies at the south end of a broad area depressed by step faulting with reference to the mountainous area directly to the south.

Vertical displacements along the faults amounting to 3000 to 4000 feet are reported by Thompson in the mountains of northwest Khurasan between Bujnurd and Maraveh-tepeh. A fault with a displacement of 7000 feet, according to this observer, borders a broad anticlinal axis which roughly follows the Atrek River west of Longitude 57°. A grid of faults was mapped by the same geologist in the region between Quchan and Gunbad-i-Qabus. Whereas the longitudinal trends in Gurgan are generally northeasterly, shifting in Khurasan to east-west and then to west-northwesterly, the alignment is reported broken by numerous transverse faults. Overthrusting is prominent in various zones between Bujnurd and Kazvin. An important system of longitudinal faults which trends from N. 50° E. to N. 70° E. bounds the mountains south of the Gurgan plains.

According to Thompson the east Gurgan area is broken by transverse faults likewise having displacements ranging from a few feet to several thousand feet. This geologist reports evidence of horizontal movements of 2000 to 3000 feet. The downthrow was usually to the west, so that one encounters progressively younger beds in travelling west from the mountains of northwest Khurasan to the Caspian Sea.

The structures of the Gurgan plains are little known, for most of them are covered with extensive silt and loess. The loess forms gently rising surfaces which are locally related to structure but not always indicative of it. Throughout Gurgan numerous artificial mounds mark the positions of ruined cities, fortifications, and walls. Aside from these features northeast Gurgan contains one or more east-trending anticlines of which the east end is Cretaceous, plunging westward beneath a Pliocene surface. Other anticlines, having a similar strike, correspond with uplifted Mesozoic and Paleozoic blocks east of the Sar Su branch of the Gurgan River.

The east-west fault alignment is not limited to the northern belt. Faults and anticlines of great length and great displacement, paralleling the Elburz, have been mapped far out into central Iran—an area called by De Böckh, Lees, and Richardson (1929, p. 62, 135-148) the "Median Mass." Relationships indicate that the fault system may have originated at the end of Cretaceous time but that it did not attain greatest development until the middle Tertiary. Although some of the central faults maintain a roughly southeasterly trend, they do not belong to the major mountain groups.

Among the great northern faults, one mapped by Reeves on the south front of a west-southwest-trending range just west of Shahrud raises the

FIGURE 3.—*Cross sections in central Elburz Mountains*
After Riviere.

Carboniferous and later limestones high above the plateau level. Some miles east, en echelon but parallel, another fault lifts the strata to the south; it has a mapped length of 75 miles (120 km.). Consequently, a broad parallelogram in which Shahrud and Maiamai are situated constitutes a graben having a maximum breadth of 17 miles (27 km.) and containing anticlines with rocks of various Tertiary epochs at the surface. The Shahrud anticline, in particular, is 30 miles (48 km.) long, broken by faults into several substructures and having folding in its incompetent beds. Shorter faults lie parallel to the major ones at Damghan and Miyandasht. A parallel anticlinal overthrust has been mapped at Rishm near Maluman.

Anticlinal trends coincide in direction with the displacements in Tertiary formations and associated lavas. For instance, the Rishm overthrust anticline brings Carboniferous to the surface in the midst of Eocene "volcanic" beds. Although anticlines having Carboniferous to Cretaceous rocks at the surface are distributed throughout the Kavir from Shahrud south to Maluman—a distance of 90 miles (144 km.)—and east nearly to Sabzawar (140 miles, or 230 km.), few of the folds are simple.

Quite a different section of country, in which faulting is likewise notable but has a north-south trend instead of a generally east-west one, lies north of the Zahidan massif. At this place Reeves, the writer, and Howard M. Kirk working in Afghan territory, independently mapped several faults which trend north-northwestward and bound the east flank of an uplifted area having a north-south strike. These faults, with downthrow to the east, formed the Seistan depression (Fig. 2), which, were the east side similar, would be a graben. The west upland border as far north as Neh consists of alternating anticlines, of moderate or steep dips, which bring Eocene shales and occasionally Cretaceous limestone to the surface in the midst of later formations.

In an intermediate area Douglas (1929, p. 626) described a prominent scarp of probably Paleozoic limestone, dipping southwest and striking northwest along the northeast flank of Kuh-i-Naiband—a mountain 8000 feet in altitude—just west of Naibandan. The scarp is reported to be a well-defined thrust, passing through Naibandan and transgressing a series of shales, calcareous sandstones, and quartzites containing Upper Triassic fossils. The plane of thrusting is marked by quartz veins and igneous intrusions.

A conspicuous characteristic of the Zagros and central Elburz mountains (Fig. 3) as well as of certain intermediate positive elements in central Iran are nappes which are sometimes several miles in lateral extent (De Böckh, Lees, and Richardson, 1929, p. 60). According to both Blan-

FIGURE 1. LOOKING DUE EAST FROM GURGAN CAMP NO. 1
Northeast Gurgan province; Ridge of Carboniferous rocks reported cut off by fault on the north.

FIGURE 2. VILLAGE ON ATREK RIVER IN NORTHWEST KHURASAN
Destroyed by recent earthquake.

FIGURE 3. OVERTURNED FOLD
Bounded by fault on right, near Fashand on Shamshak road north of Tehran.

VIEWS IN NORTHEAST IRAN

FIGURE 1. MASSIVE SANDSTONE OF UPPER CRETACEOUS AGE
Capping hill northeast of Muzduran Pass, northeast Khurasan province.

FIGURE 2. STREAM-CUT GORGE THROUGH LOWER CRETACEOUS LIMESTONE
47 miles east of Maraveh-tepeh on road to Quchan, northwest Khurasan province.

CRETACEOUS ROCKS OF NORTHEAST IRAN

ford and Tipper the nappe region extends as far as Geh in southeast Iran. Although obvious structures of the nappe type are not known between Bampur and Kerman on the south to Nishapur and Samnan on the north, it is possible that they may exist. The structure is likewise very complicated southwest of the Dasht-i-Lut. Anticlines, synclines, overturned folds, and faults are numerous in strata from the Lias upward. Schenck mentions a "seismically active" fault east of Kerman corresponding to the west side of a mountain range.

Along the east boundary of Iran a series of basins may be in part of graben nature (Huntington, 1905, p. 231). Duplications of faulting on the major trend in this region were found by Howard M. Kirk in extreme southwest Afghanistan, north of Kuh-i-Malik Siah, and again by the author between Nok-kundi (British Baluchistan) and Mirjawa (Iran). Huntington places the Hari Rud Valley in this category. Some evidence of the existence of a probable graben is found in geologic mapping in the area west of the Seistan basin (Fig 2).

Another type of fold is reported by Thompson and Hotchkiss in the vicinity of Sib and Disak, 100 miles (160 km.) southeast of Khash [3] in southeast Iran. Tightly compressed anticlines are said to attain angles from 60 degrees to nearly vertical. The strikes in the southeastern areas are from east-west to north-northwest.

The age of the folding may be important to a correct understanding of Asiatic tectonics. Evidence exists in the Elburz mountains and the northeast that Permo-Carboniferous beds were much disturbed in pre-Cretaceous time. Another notable period of folding commenced in post-Eocene time and probably continued through the Miocene.

The persistence of movements in the mountains of northern Khurasan has been evinced by violent earthquakes (Huntington, 1905, p. 236) which destroyed old Quchan—the place where the Meshed fault ends in a flexure—and other cities and villages in the same structural belt from Khurasan westward through Gurgan and Mazandaran. The frequent destructive earthquakes of northern Iran (Pl. 5, fig. 2) result from renewed movement along major fault lines. Intensive vibrations take place throughout the region from Mazandaran southward to the plain of Bampur. Although Kerman and Ravar are reported especially susceptible, hardly any part of eastern Iran is free from earthquakes.

Thompson (1938) reported evidence of recent distortion in beds of Pliocene age in eastern Gurgan. He based this contention on the fact that ruins of ancient civilizations are fed by well-graded water ditches which once tapped the Yele-Adji and Gurgan rivers nearly 180 feet above the level of the present stream courses for the purpose of irrigating the (now)

[3] Also spelled Khwash and Vasht.

highest of several well-defined terraces. He calls attention to the continuance of movement up to the present time as evinced by the frequency of earthquakes in the region. Faulting in the loess is additional evidence of Quaternary faulting (Pl. 4, fig. 1).

GEOLOGIC COLUMN AND MAP OF EASTERN IRAN

The character, stratigraphic position, structural attitude, distribution, and fossils from strata described in the following pages are the author's compilation from the data submitted by field geologists to the offices of Amiranian Oil Company, supplemented by the literature. Similarly the coordinated areal extent of rocks of various ages is represented on Plate 1. Direct contributors to recent knowledge are Schenck, Reeves, and Thompson. The work of Howard M. Kirk in southwest Afghanistan is used in trans-frontier correlations. Table 7 is a generalized composite column for eastern Iran, based on a tentative column prepared by Schenck for Amiranian Oil Company as of November 9, 1937, amplified by the writer for present purposes.

In compiling the map the necessity has become increasingly evident for exercising caution as to acceptance of earlier mapping derived from any source or even present mapping based on interpretations of the work of a single individual. Marked differences in correlations and in assumed map positions exist in any region devoid of base maps and in surveys of identical terrane made by two or more conscientious geologists working independently. It is necessary to refrain from accepting much of the early mapping, although it be considered classic, until further checked in the field. On Plate 1 the ages of the rocks are mapped as originally given except in cases where new data have rendered old assignments incorrect.

The above statement applies in particular to a published map by Stahl (1895) covering the Elburz region as far east as Shahrud. It is now impossible, in any office coordination, to reconcile his work in the mountains between that city and Gurgan with observations recently made by Thompson, Reeves, and the author. Similarly, Stahl's results in the central Elburz region differ in many respects from those recently obtained by Rivière.

PRE-CAMBRIAN ROCKS

Although the oldest rocks known with certainty to exist in eastern Iran are Cambrian, several observers have reported gneissic and schistose rocks which may be older. Metamorphic rocks in south-central Iran were first described by Tipper (1921, p. 54-55) from localities 20 to 50 miles (30

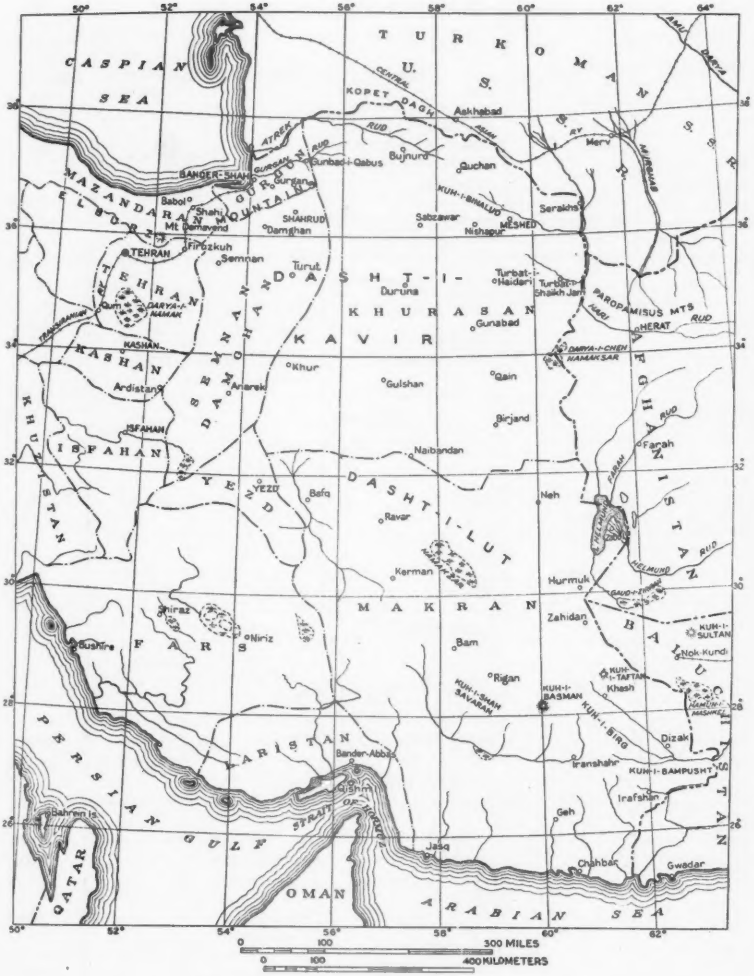

FIGURE 4.—*Index map of eastern Iran*
Showing provincial boundaries, principal towns, and drainage.

to 80 km.)[4] northeast of Bandar 'Abbas, specifically near Khanu and in Rudkha-Duzdan valley as far as Barinti. Tipper mapped similar exposures midway between Iranshahr and Chahbar.

[4] Distances mentioned herein are approximate air-line distances unless otherwise stated.

TABLE 7.—*Geologic column for eastern Iran*

Era	System	Series	Group, etc.	Geol. Survey of India's Subdivisions	Feet (max. known)
Quaternary	Recent	Artificial mounds, alluvium, fanglomerates, gravels, lake deposits, travertines			500
	Pleistocene	Fanglomerates, gravels, lake deposits, loess			1000
		Unconformity			
Tertiary	Pliocene	Fossiliferous beds, loess, gravel, clay	Aktchagil		360
			Bakhtiari, Kunji Rud etc.	Siwalik	15,000
		Unconformity			
	Miocene	Fars*	Pontian Sarmatian Tortonian Burdigalian	Makran	20,000
	Oligocene	Asmari*	Aquitanian		
		Khamir	Stampian	Nari	300
	Eocene	Upper Eocene	"Green beds" ?		10,000
		Middle Eocene	Lutetian and others	Khirthar	500
				Laki	
		Lower Eocene		Ranikot	6000
		Local Unconformity			
Mesozoic	Cretaceous	Upper Cretaceous	Danian		350
			Maestrichtian Campanian		900
			Santonian Coniacian		500
		Middle Cretaceous	Turonian		4600
			Cenomanian		1000
		Lower Cretaceous	Albian		1500
			Aptian		1000
			Local Unconformity		
			Barremian Hauterevian Valanginian Infra-Valanginian		4000

* Group or formation (preferably the former).

TABLE 7.—*Geologic column for eastern Iran*—Continued

Era	System	Series	Group, etc.	Geol. Survey of India's Subdivisions	Feet (max. known)
		Unconformity (except locally)			
Mesozoic	Jurassic	Upper Jurassic	Tithonian Kimmeridgian Oxfordian Callovian		2500
		Middle Jurassic	Bathonian Bajocian		3500
	Lias	Lower Jurassic	Toarcian Pleinsbachian		4000
		Unconformity ?			
	Triassic	Upper Trias	Rhaetian Norian Carnian		2000+
		Middle Trias	Ladinian Anisian		
		Lower Trias	Scythian (not recognized)		
		Unconformity			
Paleozoic	Permian				5000
	Carboniferous	Upper Carboniferous	Uralian		
		Middle Carboniferous	Moscovian		
		Lower Carboniferous	Viséan Tournaisian		
		Local Unconformity			
	Devonian	Upper	Famennian Frasnian		2000
		Middle	Givetian ? Eifelian		
		Lower	"Old Red Sandstone"		
	Ordovician and Silurian ?				
	Cambrian			Hormuz	7000
		Unconformity			
Proterozoic ?	Pre-Cambrian ?	Lower Huronian ?	"Hatát" ?	Dharwar ?	5000

Intrusive, extrusive and tuffaceous rocks of many ages;
Metamorphic rocks of unknown ages.

In the Bandar 'Abbas area were found epidote schists, crushed serpentines cut by asbestos veins, sericitic schists containing spinel, chlorite schists, and actinolite schists. These formations are pierced in all directions by white quartz veins, and bands of crystalline limestone are infolded. Pilgrim (1908) considered the Hatát series of Oman as questionably Archean, and Tipper suggested possible identification with the Dharwar system of India.

On his journey over the highway between Yezd and Meshed, Furon (1937a, p. 36) found a metamorphic and igneous area between Rizab and Pusht-i-Badam, 55 miles (89 km.) to 140 miles (224 km.) northeast of Yezd. The rocks are mainly marbles, schists, gneisses, fine-grained igneous rocks, and granites. Southwest from Pusht-i-Badam lie amphibolites, mica schists, quartzites, and intruded gneisses, which are, according to Schenck, over 5000 feet thick. This area was considered by Furon as "pre-Cambrian" but is conceded by Schenck to be merely "pre-Aptian."

Again, near Tel-i-Siah (position not identified) in the Bam region, Thompson discovered mica schists; he states that

> "Eocene rocks appear to lie directly on this ancient metamorphic basement to within relatively a few miles east from Nosratabad-Sipi."

CAMBRIAN SYSTEM

The oldest rocks of which the age is known with certainty are Cambrian. Trilobites of Middle Cambrian age were collected by Messrs. R. C. Jennings and K. W. Gray at Kuhbanan, 90 miles (145 km.) N. 30° W. from Kerman and were determined by King (1930, p. 316-317) as *Redlichia chinensis* Walcott and *Anomocare megalurus* (Dames). Cambrian fossils are, however, better known in the Bakhtiari and Kuh-i-Dinar areas of southwest Iran (described in the same paper) where Lower and Upper Cambrian shales, micaceous sandstones, dark limestones, dolomites, and gypsum exist. Lees (1938, p. 142) estimates the maximum Cambrian thickness as possibly 7000 feet.

In addition to "normal exposures" the Cambrian of southwest Iran is associated with numerous salt plugs, first called by Pilgrim (1908, p. 14-53) the "Hormuz series," and erroneously assigned by him to the "Upper Cretaceous or Lower Eocene." Blanford (1872, p. 42), however, had contended the salt formation in and near Hormuz is "far more ancient" than rocks of the Makran group and had added (p. 43):

> "I can form no conception of the age of these salt beds; they are much disturbed, but beyond the fact of their being much older than the Makran group, there is nothing to indicate their geological relations."

The age of the "Hormuz series" was definitely determined by Lees (1927, p. 30) through the discovery of Middle Cambrian trilobites at Al-busa

on the Persian Gulf. Harrison (1930, p. 478) has postulated an extension of the salt formation into horizons both slightly higher and considerably lower.

ORDOVICIAN AND SILURIAN SYSTEMS

Ordovician or Silurian rocks are reported in southwest Iran in a single locality, at Furgun, north of Bandar 'Abbas (Lees, 1938, p. 142); they

TABLE 8.—*Devonian system in eastern Iran*

American classification	European divisions	Groups reported in eastern Iran
Upper Devonian	Neodevonian	Famennian
		Frasnian
Middle Devonian	Mesodevonian	Givetian ?
		Eifelian
Lower Devonian	Eodevonian	Lower part of "Old Red Sandstone"

consist of dark fissile graptolitic shales and white quartzites associated with some quartzitic sandstones. In northwest Iran the Ordovician has been reported by Dietrich (1937). Rocks of these ages are, however, unknown in eastern Iran. It is true that Grewingk (1853, p. 171) mentioned the occurrence of Silurian at "Chalikhán," west of Shahrud, and in foothills "south of Chalikhán," but Blanford (1876, p. 442) suggests that these rocks may be of Devonian age.

DEVONIAN SYSTEM

Throughout much of Asia the Middle or the Lower Devonian lies unconformably upon older Paleozoic rocks, and observations in Iran give a similar impression. The existence of Devonian strata was early reported by De Verneuil from collections made by De Hell, the results of which were published by Viquesnel (1850), from (1) A somewhat vague locality described as being on the southern slopes of the mountain plateau of "Tchéhennemé," and from (2) the central axis of the Elburz chain "between the Nika Rud and valley of the Touva," about 60 miles (100 km.) southwest of Gurgan. Blanford (1876, p. 406) next reported Devonian rocks north of Tehran, but some of these appear to be Carboniferous. The Devonian system is, however, present in parts of eastern Iran. Table 8 gives the determined sequence.

In northeast Iran the Devonian directly underlies the Carboniferous system with general but apparently not universal conformity. Unfossiliferous red sandstones, believed to belong to the "Old Red Sandstone"

series, are exposed in the Elburz, notably in the Shamshak, Zaigun, and Germab areas within 20 to 24 miles (35 to 40 km.) northerly from Tehran. Stahl (1911, p. 10) states that the "Old Red Sandstone" facies seems to thin out, since it is about 1000 feet thick at Tehran but absent in the Kohrud Mountains, 250 miles (400 km.) to the south, between Kashan and Isfahan.

Reeves (R-23)[5] reports 2000 feet of these shales, limestones, and gypsums at a place 4 miles (7 km.) north from Amaria (5 miles or 8 km. north from Shahrud). In the Shah Kuh region, between Shahrud and Gurgan, according to Rivière (1934, p. 9-10), this series is overlain by limestone carrying Frasnian and possibly Givetian fossils. Reeves also reported lenses of fossiliferous black limestone, much veined, near Demavend, Ara Kuh, and Chalus. Thompson and others mention 1000 feet of Devonian, consisting of yellow to light-brown sandstone, sandy shale, jet black limestone, and bright red medium-grained sandstone, all separated from Cretaceous rocks by a fault, between Darband and Germah (near Jajarm), 28 to 66 miles (45 to 105 km.) southwest from Bujnurd. Reeves reports a partial section in some detail between Shahrud and Jajarm:

Section between Shahrud and Jajarm

	Feet
3. Gypsum	100
2. Brownish-black fossiliferous limestone with brown sandstone in basal portion	300
1. Gypsum; and buff, brown, green, grey, and red fossiliferous layers	500
Total	900

Furon (1937a) reported Paleozoic rocks, questionably assigned to Devonian age, on a pass 37 miles (60 km.) northeast from Gulshan.

Limestones of Upper Devonian age are found in northwest Iran and in the central Elburz, where they "grade downwards" into "Old Red Sandstone." Marine Upper Devonian fossils were mentioned by Stahl (1911, p. 9) from a locality 10 miles (16 km.) northeast from Damghan, and by Muller (R-23) from 4 miles (7 km.) northwest from Amaria (8 km. north from Shahrud). Upper Devonian rocks were recently confirmed by Muller (R-13) from a point a mile west from Namaha or 22 miles (35 km.) N. 20° W. from Damghan. Krumbeck (1922) listed numerous Upper Devonian forms coming from the Elburz Mountains and Khurasan. Upper Devonian fossils have since been determined by Muller from a locality (R-75) near the base of Kuh-i-Shutari, 10 miles (16 km.) northeast from Gulshan. Devonian fossils were also determined by Muller in

[5] For the sake of authentication the field designations of localities from which fossil collections were made by geologists of Amiranian Oil Company are preserved in this paper prefixed by the geologist's initial. The identity of these prefixes is as follows: A=Afshar, B=Buie, C=Clapp, H=Hotchkiss, R=Reeves, S=Schenck, T=Thompson.

TABLE 9.—*Devonian fossils of northern Iran*

Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Adolfia ziczac F. A. Roemer													x			
Asteropyge (*Metacanthus?*) *persica* R. and E. Richter ("*Cryphaeus* aff. *supradevonico* Frech" Krumbeck)					x								x			
Athyris concentrica (von Buch)					x	x					x					
Atrypa aspera V. Schlotheim													x			
A. boloniensis d'Orbigny											x					
A. reticularis (Linne)					x											
A. sp.																x
Bellerophon cf. *verae* Frech									x							
Beloceras sagittarium Sandberger																x
Bostrichopus cf. *antiquus* Goldfuss													x			
Camarotoechia sp.														x		
Cardiola sp.												x				
Cyathophyllum sp.											x					
Cyrtospirifer supradisjunctus Obrut														x		
Dalmanella sp.				x												
Entomis cf. *serratostriata* Sandberger													x			
Euomphalus sp.											x					
Favosites sp.													x			
Leiorhynchus crenulatus Gosselet				x												
Leptaena colombarii Viquesnel											x					
Lithostrontion sp.													x			
Martinia inflata Schnur													x			
Naticopsis marthae Frech									x							
Nyassa dorsata (Goldfuss)										x						
Orthis arcuata Phillips	x															
O. devonica (d'Orbigny)											x					
O. orbicularis Sowerby											x					
O. striatula (Schlotheim)											x					
O. sp.						x										
Orthoceras sp.																x
Orthothetes chemungensis (Conrad)					x											
Panenka sp. Barrande									x							
Paracyclas rugosa (Goldfuss)										x						
Phacops latifrons Burmeister						x										
Phtonia cf. *loczyi* Reed									x							
Productella forojuliensis Frech	x															
P. herminae Frech	x															
P. hirsuta Hall var. *calva* Wenjukow						x										
Productus fallax Pand.													x			
P. murchisoni Koninck											x					
P. subaculeatus Murchison											x					
Retepora sp.											x					
Rhynchonella var. *cilico-armenica* Frech			x													
R. elliptica Schnur										x						
R. implela (Sowerby)			x													
R. letiensis Gosselet				x		x			x							
R. livonica (von Buch)		x														
R. omalius Gosselet							x									
R. cf. *pleurodon* (Phillips)		x														
R. pugnus (Martin)		x														
Schizophoria excellus Grabau																x
Spirifer anossofi De Verneuil in Murchison					x						x					

[*See references on page 30*]

TABLE 9.—*Devonian fossils of northern Iran*—Continued

Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
S. archiaci Murchison				x				x			x	x				
S. aff. *bifido* F. A. Roemer												x				
S. comprimatus Schlotheim															x	
S. inflatus Schnur					x	x										
S. cf. *pamiricus* Reed														x		
S. seminoi (cf. *S. anossofi* De Verneuil)											x					
S. seminoi De Verneuil	x															
S. speciosus (Schlotheim)																x
S. verneuili (Murchison)	x	x	x			x										
Streptorhynchus (*Orthothetes*) *umbraculum* (Schlotheim)						x										
Strophodonta sp									x							
Tentaculites aff. *inaequalis* Eichwald													x			
T. tietzei Stahl					x											
T. sp								x								
Terebratula scalprum Roemer											x					
T. (2 or 3 other species)											x					
Tornoceras aff. *retrorsus* Buch																x
Waldheimia whidborneі Davidson										x						

Localities of collections:

1. Musha, 4 miles (6 km.) northwest from Demavend village (Rivière, 1934a, p. 11).
2. Dorun (Rivière, 1934a, p. 11).
3. South of Nisa in Karaj valley, 40 miles (64 km.) north-northwest from Tehran (Rivière, 1934a, p. 11).
4. North of Deh-i-mulla, midway between Damghan and Shahrud (Stahl, in limestone above "Old Red Sandstone").
5. Between Kelbehide and Saturwar (Stahl, 1911, p. 10).
6. Directly north of Damghan, between Shah-kuh-pain and Chahar-deh in dark limestones (Stahl, 1911, p. 10).
7. Mobarecke, 4½ miles (7 km.) north from Rudahan (Rivière, 1934a, p. 10).
8. In black limestones between village of Serasch and Abbid caravanserai, 21 miles (34 km.) north from Kerman on road to Ravar (Stahl, 1911, p. 10).
9. Northwest Iran, in Upper Devonian limestones and shales (Rieben, p. 23-24).
10. Near Suh in the Koh-rud Mountains, between Kashan and Isfahan (Stahl, 1911, p. 9).
11. Village of Touwa (location not known).
12. Elburz region (Krumbeck, 1922).
13. Khurasan (Krumbeck, 1922).
14. Upper Devonian from 1 mile north from Namaka; 22 miles (35 km.) N. 20° W. from Shahrud (R-13).
15. 15 miles (24 km.) north from Sandadio and 12 miles (20 km.) S. 30° W. from Kashmar (Muller, R-72).
16. Near base of Kuh-i-Shutari, 10 miles (16 km.) N. 50° E. from Gulshan (Muller, R-75).

collections (R-72) from 15 miles (24 km.) north from the Sandadio and 12 miles (19 km.) S. 30° W. from Kashmar (formerly Turshiz). Table 9 is a list of the Devonian forms reported from various localities in northeast Iran.

CARBONIFEROUS SYSTEM

PRINCIPAL FEATURES

Distribution and subdivisions.—The Carboniferous system, first mentioned by Blanford (1876, p. 442), has long been known to be widely

distributed in northeast Iran. Carboniferous rocks crop out as far south as Kerman and they may underlie most of eastern Iran with a thickness ranging up to 5000 feet. Where seen in northwest Khurasan the rocks are usually metamorphosed and often intensely folded and faulted. Although in Iran the Carboniferous is supposed to be generally conformable upon the Devonian, the two systems are locally separated by an unconformity. The Carboniferous subdivisions are named in Table 10.

TABLE 10.—*Carboniferous system in eastern Iran*

American classification	Divisions recognized in eastern Iran	Groups reported in eastern Iran	
Pennsylvanian	Upper Carboniferous	Uralian	
	Middle Carboniferous	Moscovian	
Mississippian	Lower Carboniferous	Dinantian	Viséan
			Tournaisian

Elburz mountain areas.—In the Elburz Mountains the Carboniferous is composed of limestones and shales, generally dark gray to black, having a thickness aggregating 1000 to 5000 feet. Griesbach (1887, p. 97) traced a dark Carboniferous limestone carrying *Productus* from Herat (Afghanistan) west to the Kuh-i-Binalud. Late Paleozoic limestones, quartzites, and basaltic lavas, intruded by various igneous rocks, are reported in the Kuh-i-Binalud. Griesbach stated that

> "the Carboniferous group shows great points of resemblance both lithologically and palaeontologically, over the entire distance from the Caucasus to the North-west Himalayas."

This series has been identified by Stahl, Rivière, and others in the Shah 'Abdul 'Azim Mountains southeast of Tehran. Much farther east is the following section, found by Reeves near Damghan, where Carboniferous strata rest on rocks of probable Devonian age:

Section of Carboniferous rocks near Damghan

	Feet
3. Brown, thin-bedded limestone, containing one sandstone bed	2500+
2. Black, well-bedded limestone	500
1. Brown-black calcareous shales and thin limestones	1500
Total	4500+

North-central areas.—Reeves reports additional sections in the Shahrud-Turut area:

Section No. 1 in Shahrud-Turut area

	Feet
Unconformity	
5. Black calcareous shale with thin beds of angular limestone pebble conglomerate bearing *Fusulina*	600
4. Red shale	100
3. Thin-bedded shaly limestone	1000
2. Dark-brown to buff calcareous shale and shaly limestone	500
1. Dark-brown to black limestone, pink at base	300
Unconformity	
Total	2500

Section No. 2 in Shahrud-Turut area

	Feet
Unconformity	
4. Gray to red, cross-bedded sandstone and quartzite	500
3. Gray to white sandstone with limonitic stains	700
2. Red cross-bedded sandstone and shale	700
1. Black crystalline limestone	100
Total	2000

Carboniferous fossils were recently collected (R-81A) at a point 26 miles (41 km.) S. 13° E. from Damghan, as well as (R-68) 3 miles (5 km.) S. 30° E. of Usbeg Kuh and 33 miles (53 km.) S. 30° W. from Duruna. Rocks of this age crop out in anticlinal positions southeast of Hasanabad (south of Damghan) and again, brought up by faulting, just northwest of Maluman.

Areas north of Elburz Mountains.—On the north side of the Elburz mountains Carboniferous limestone was found near the level of the

TABLE 11.—*Carboniferous fossils from south-central Iran*

Name	1	2
Athyris cf. *roiysii* Léveillé	x	.....
Choetetes sp	.....	x
Crinoid stems	x	x
Dielasma sp	x	.....
Fenestella sp	x	x
Lonsdaleia floriformis Lonsdale var	.....	x
Orthis sp	.....	x
Polypora sp	.....	x
Poteriocrinus ?	x	.....
Productus sp.*	.....	x
Rhynchonella sp	x	.....
Spirifer "striatus" Bolland	.....	x
S. sp	x	.....
Stenopora sp	x	.....
Tentaculites sp	.....	x

* Collected by Pilgrim.

Localities of the collections:

1. Hutk, on road from Sir-i-Asiab (18 miles or 29 km. northwest from Kerman) to Hizumi.
2. 2 miles (3 km.) northeast from Hizumi.

Gurgan plains in a belt which passes within 9 miles (15 km.) southeast of Gunbad-i-Qabus (T-6) and extends to about 20 miles (32 km.) northeast of the same town. On the west side of Behli Dagh, 37 miles (60 km.) northeast from Gunbad-i-Qabus, Thompson and others report (Pl. 5, fig. 1) 900 feet of dark-gray to black, thin-bedded to flaggy, probably Carboniferous limestone having thin shaly and ferruginous partings.

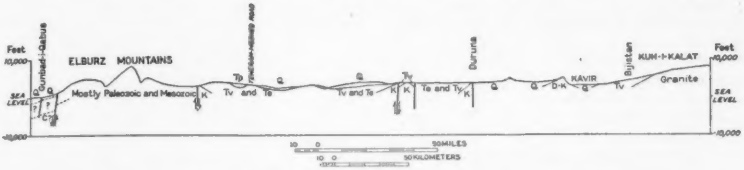

FIGURE 5.—*Hypothetical cross section in northeast Iran*

From Gurgan plains to center of plateau. By Amiranian Oil Company.

Coordination by F. G. Clapp. Q, Quaternary; Tp, Pliocene; Te, Eocene (mainly sedimentary rocks); Tv, Eocene (mainly igneous rocks); C-J, Carboniferous to Upper Jurassic; K, Cretaceous.

South-central areas.—Tipper (1921, p. 55-56) reported Carboniferous limestones in two places northwest of Kerman. The fossil collections named in Table 11 indicate this age.

Central-eastern areas.—Furon is vaguely reported to have found Paleozoic fossils near Kalmarz (40 miles or 64 km.) west-southwest from Gulshan. Farther to the northeast Carboniferous rocks were discovered by him in positions intermediate between Lias and possible Devonian on a pass 37 miles (60 km.) northeast of Gulshan. A coal series as well as "Upper Paleozoic" fossils are cited by Schenck west of Duhak. Reeves reports black fossiliferous limestone overlying variegated shale and ferruginous sandstone in the mountains east and northeast of Gulshan, thence northeast to Kashmar. Still farther to the southeast "unassigned upper Paleozoics" were described by Douglas (1929, Pl. 42) at Kuh-i-Naiband, near Naibandan. Thus a great Carboniferous area appears to underlie more recent rocks throughout the country east of the Dasht-i-Kavir. The fundamental relationships will be evident from a study of Figure 5.

LOWER CARBONIFEROUS SERIES

Rocks of "Lower Carboniferous" or approximately Mississippian age were perhaps first recognized in the Elburz Mountains by Blanford (1872, p. 455-456) who reported the presence of *Gigantella gigantea, Streptorhynchus cremistria, Spirifer* sp., *Retopora* sp., and plant forms. De Morgan (Douvillé, 1904, p. 192) found the Dinantian series repre-

TABLE 12.—*Fossils from Lower Carboniferous rocks in northern Iran*

(T=Tournaisian; V=Viséan)

Name	1	2	3	4	5	6	7	8	9	10	11	12	13
Actinoconchus planosulcata (Phillips)	....	....	xV	....	....	....	....	....	....	....	....	....	....
Athyris expansa (Phillips)	....	....	xV	....	....	....	....	....	....	....	....	....	....
A. roissii Léveillé	xV	....	....	....	....	....	....	....	....	....	....	....	....
Buxtonia scabricula (Martin)	....	xV	....	....	....	....	....	....	....	....	....	....	....
B. sp.	....	....	....	....	....	....	xV	....	....	....	....	....	....
Caninia cylindrica Scouler	....	....	....	x	....	....	....	....	....	....	....	....	....
C. patula Michelin	....	....	....	....	....	....	....	....	....	....	x	....	....
Chonetes buchiana de Koninck	....	....	....	....	....	....	....	....	....	xV	....	....	....
C. hardrensis (Phillips)	....	xT	....	....	....	....	....	....	....	....	....	....	....
C. papilionacea	xV	....	....	....	....	....	....	....	....	....	....	....	....
Cyathophyllum (*Palaeosmilia*) *murchisoni* Milne-Edwards and Haime	....	....	....	....	....	xV	....	....	....	....	....	....	....
Davieseilla comoides (Sowerby)	....	....	....	....	....	xV	....	....	....	....	....	....	....
Dielasma cf. *hastata* (Sowerby)	....	....	....	....	....	....	xV	....	....	....	....	....	....
Euomphalus pentangulatus Sowerby	x	....	....	....	....	....	....	....	....	....	....	....	....
Favosites aff. *fibrosa* (Goldfuss)	....	....	....	....	....	....	....	....	....	....	....	....	xV
Hallia cylindrica Milne-Edwards and Haime	....	....	....	....	....	xV	....	....	x	....	....	....	....
Martinia glabra (Martin)	xT	....	....	....	....	xV	xV	....	....	....	....	....	....
Michelinia favosa Goldfuss	xT	....	....	....	....	....	....	....	....	....	....	....	....
M. grandis MacCoy	....	....	....	....	....	....	xV	....	....	....	....	....	....
Orthis sp.	....	....	....	....	....	....	....	....	x	....	....	....	....
Orthothetes crenistria (Phillips)	xV	....	....	....	....	....	....	....	....	xV	....	....	xV
Productus cora d'Orbigny	....	xV	....	....	....	xV	xV	....	....	....	....	....	xT
P. corrugatus MacCoy	....	....	....	....	....	xV	....	....	....	....	....	....	....
P. costatus Sowerby	....	....	....	....	....	....	xV	....	....	....	....	....	xV
P. derbiensis Muir-Wood	....	xV	xV	....	....	....	....	....	....	....	....	....	....
P. giganteus (Martin) Sowerby	x	....	....	....	....	....	....	....	....	....	....	....	....
P. insculptus Muir-Wood	....	....	xV	....	....	....	....	....	....	....	....	....	....
P. lobatus Sowerby	....	....	xV	....	....	....	....	....	....	....	....	....	....
P. cf. *longispinus* Sowerby	xV	xV	xV	....	....	....	....	....	....	....	....	....	....
P. margaritaceus Phillips	....	....	....	....	....	....	....	....	....	xV	....	....	....
P. aff. *minatus* Muir-Wood	....	....	....	....	....	....	....	....	....	xV	....	....	....
P. perlongus	x	....	....	....	....	....	....	....	....	....	....	....	....
P. pinguis Muir-Wood	....	....	....	....	....	....	....	....	....	xV	....	....	....
P. postulatus Phillips	....	....	....	....	....	....	....	....	....	xV	....	....	....
P. semireticulatus (Martin)	xV	....	....	....	....	....	xV	....	....	....	....	xV	xV
P. striatus (Martin)	xV	....	....	....	....	....	....	....	....	....	....	....	....
P. sulcatus Sowerby	....	....	....	....	....	....	xV	....	....	....	....	....	....
P. vaughani Muir-Wood	....	xV	....	....	....	....	....	....	....	....	....	....	....
P. sp.	....	....	....	....	....	....	....	....	x	....	....	....	....
Reticularia lineata (Sowerby)	....	....	....	....	....	....	xV	....	....	....	....	....	xT
Rhynchonella pleurodon (Phillips)	x	....	....	....	....	....	....	....	....	....	....	....	....
Saccamina carteri Brady	....	....	xV	....	....	....	....	....	....	....	....	....	....
Schizophoria resupinata (Martin)	....	....	....	....	....	....	....	x	....	....	....	....	....
Spirifer cuspidatus (Martin)	xT	xV	....	....	....	....	....	....	....	....	....	....	....
S. "*striatus*" Bolland	xV	....	....	....	....	....	....	....	....	....	....	....	....
S. tornacensis d'Archiac	xT	xT	....	....	x	....	....	....	....	....	....	....	xT
Syringopora sp.	....	....	....	....	....	xV	....	....	....	....	....	....	....
Zaphrentis enniskillenі Milne-Edwards and Haime	....	....	....	....	....	....	....	x	....	....	....	....	....
Z. omaliusi Milne-Edwards and Haime	....	....	xV	....	....	....	....	....	....	....	....	....	....
Z. sp.	....	....	....	....	....	x	x	....	....	....	....	....	....

Localities of Collections:

1. Near village of Musha, in south flank of Imam-Zadeh-Hachim range northwest of Demavend village (Stahl, 1911, p. 11).

(*Continued on bottom of next page*)

sented by *Productus postulosus, P. punctatus, P. semireticularis, Spirifer striatus,* and *Syringothyris cuspidata.* Krumbeck (1922) recognized Tournaisian and Viséan fossils in the Elburz region. Carboniferous rocks are also found in outlying anticlines a short distance south of the Elburz.

TABLE 13.—*Fossils from Upper Carboniferous series in North Iran*

Name	1	2	3	4	5
Dielasma sp		x			
Fusulina aff. *regularis* Schellwien				x	
Meekella delepinei Rivière		x			
Neospirifer sp					x
Productus fascinatus Kutassy		x			
P. gratiosus Waagen		x			
P. gruenewaldti Krotow		x			
P. striatus (Martin)	x				
P. vishnu Waagen		x			
Reticularia lineata (Sowerby)		x			
Sphaerocodium cf. *bornemanni* Rothpletz				x	
Spirifer glaber (Sowerby)	x				
S. mosquensis Fischer de Waldheim	x	x			
S. rajah Salter			x		
Spiriferina ornata Waagen		x			
Streptorhynchus pelargonatus (Schlotheim)		x			
Zaphrentis sp					x

Localities of collections:

1. Menjil district, between Kazvin and Rasht (Stahl, 1911, p. 19).
2. Shah 'Abdul 'Azim Mountains (Stahl, 1911, p. 19-20; Rivière, 1934a, p. 19), in fucoid limestones above Viséan beds.
3. In Chalus valley, north of Hazar-cham (Rivière, 1934a, p. 21).
4. Elburz region (Krumbeck, 1922).
5. One mile west from Namaha and 35 km. N. 20° W. from Damghan (R-9, determined by Muller).

"Lower Carboniferous" fossils from definite localities, determined by various observers, are listed in Table 12.

MIDDLE AND UPPER CARBONIFEROUS SERIES

The Middle and Upper Carboniferous series of northeast Iran appear to be related to those of the Ural Mountains, Turkey, the Himalaya Mountains, and the Indian Salt Range. In Iran, south of the Elburz

2. Near village of Mobarecke, west from No. 1, and 4 miles (7km.) north from Rudahan (Rivière, 1934a, p. 17).
3. Near Darbend-i-sar, west of Shamshak (Rivière, 1934a, p. 17).
4. East of Shamshak (Rivière, 1934a, p. 17).
5. 12 miles (19 km.) west from Firuzkuh (village), in Delitchai valley north of bridge on Tehran road (Rivière, 1934a, p. 17).
6. Gudak Pass, north of Firuzkuh village, in black limestones (Rivière, 1934a, p. 18).
7. Shah 'Abdul 'Azim Mountains, southeast of Tehran (Rivière, 1934a, p. 18).
8. Near Alamol, in Chalus valley, 37 miles (59 km.) north from Tehran, in black limestone in *fenster* under "Old Red Sandstone" (Rivière, 1934a, p. 18).
9. In Chalus valley, northwest from Valiabad, 40 miles (64 km.) north from Tehran (Stahl, 1911, p. 10).
10. Near Mikhsaz, in Kudjour valley, perhaps 40 miles (64 km.) north from Tehran and east of Chalus valley, in black shales (Rivière, 1934a, p. 18).
11. Near Kitan, in same region as No. 10 (Rivière, 1934a, p. 18).
12. Near Pouhl, in same region as No. 11 (Rivière, 1934a, p. 18).
13. Elburz region (Krumbeck, 1922).

Mountains, the Upper Carboniferous rocks were found (R-16) one mile (2 km.) north from Namaha and also (R-9) one mile west from Namaha which lies 22 miles (35 km.) N. 20° W. from Damghan. On the north side of the mountains an exposure (T-6), 9 miles (15 km.) southeast from Gunbad-i-Qabus, carries abundant fusulinid Foraminifera, determined by Schenck as belonging to the subfamily Schwagerinae Dunbar and Henbest, dating the outcrop as not older than mid-Pennsylvanian (Moscovian) nor younger than Permian. Stahl, Rivière, and Krumbeck report pertinent Upper Carboniferous fossils from in and near the Elburz system.

PERMIAN SYSTEM

Rocks of Permian age are known both in southwest and northwest Iran (Bonnet, 1912, p. 303-318; Krumbeck, 1922). Although the system has been generally considered absent from northeast Iran, Furon (1937b) has now reported Permian limestones in the central Elburz. Permian fossils were likewise recently determined from near the base of Kuh-i-Shutari (R. 76, R. 77), 10 miles (16 km.) northeast from Gulshan. Other species of possible Permian age (R-73A) were found in a gorge 3 miles (5 km.) S. 80° E. from Aspak and 25 miles (40 km.) southeast from Gulshan. In a collection marked as derived from 40 miles (64 km.) S. 60° E. from Samnan ("R-84") *Linoproductus lineatus* (Waagen) was determined by Muller, indicating Permian age. Abundant Permian fusulinids were found by Schenck about 13 miles (21 km.) southeast from Gunbad-i-Qabus, and he reports (T-6) the presence of fusulinid foraminifers of the subfamily Schwagerinae Dunbar and Henbest. (See Elias, 1937, p. 286-287.) It is therefore possible that this outcrop may be of Permian age, which would modify the mapping of some portion of the Carboniferous area in Plate 1.

TRIASSIC SYSTEM

In west and southwest Iran, according to Lees (1938, p. 142), massive Triassic limestones unconformably overlie rocks of Permian age, the beds tentatively assigned to this system having a thickness of from 2000 to 3000 feet. Triassic rocks in northern Azerbaijan were described by Bonnet (1912, p. 212 and 320). In eastern Iran, they may aggregate about 1200 feet, subdivided as in Table 14.

In the Elburz Mountains Triassic rocks were first distinguished from Permian strata by Stahl (1911, p. 12) through discovery of Rhaetian plant-bearing beds. Fossiliferous Triassic was later found by Niedermayer (Krumbeck, 1921) and then by Hedin (Dietrich, 1927). Douglas, when studying collections made by Messrs. R. C. Jennings and K.

Washington Gray for Anglo-Iranian Oil Company, found a rich fauna of Triassic age near Naibandan (1929). Kühn (1938, p. 76-78) has further described Upper Triassic collections from south-central Iran. According to Rivière (1934, p. 26) Triassic limestones are known (1) In the upper Jajrud valley and its tributaries 22 miles (35 km.) north-northeast from

TABLE 14.—*Triassic system in eastern Iran*

American classification	European series	Groups reported eastern Iran
Upper Triassic	Keuper	Rhaetian Norian Carnian
Middle Triassic	Muschelkalk	Ladinian Anisian
Lower Triassic	Bunter	Scythian

Tehran, (2) near Abbasabad in the Talar valley 13 miles (21 km.) northeast from Firuzkuh village, (3) near the villages of Demavend and Rudahan, (4) near Jahbun and Saidabad on the Tehran road 17 and 36 miles (27 and 58 km.) west from Firuzkuh, (5) in the Karaj valley 24 miles (38 km.) north from Tehran, and (6) in the Shah 'Abdul 'Azim Mountains (Krumbeck, p. 19), 8 miles (13 km.) southeast from Tehran. In the last locality Lower Triassic fossils were found by Niedermayer (Krumbeck, 1922, p. 19), reported by Rivière (1934, p. 26), and confirmed (S-371) by Muller. Krumbeck mentions Anisian, Ladinian, Carnian, and Rhaetian beds as present in the Elburz.

From south-central Iran Dietrich (1927) reported the occurrence of Upper Triassic rocks with *Pseudomonotis ochotica* in the collections made by Sven Hedin (his numbers 77, 78, 81, and 82) at a locality 19 miles (30 km.) westerly from Gulshan. Still farther to the southeast Douglas (1929, p. 627-647) described Middle and Upper Triassic fossils based on collections made by Messrs. Jennings and Gray beneath (1) An overthrust fault plane on Kuh-i-Naiband and (2) at other points not far to the south. The normal relationship between Triassic and underlying Carboniferous rocks was not determined. Some highly disturbed black limestones ("Hauz-i-Khan group") of Rhaetian age are richly fossiliferous. Beneath these rocks lies a calcareous sandstone or quartzite series of Norian age, the fauna consisting entirely of lamellibranchs, some large. In the vicinity of Hauz-i-Sheikh, the lowermost group consists of grayish and greenish shales replete with small gastropods and small lamellibranchs. More recently Schenck determined Tri-

TABLE 15.—*Triassic fossils from eastern Iran*

Name	1	2	3	4	5	6	7
Actaeonina scalaris (Muenster)				x			
Aulacothyris sp					x		
Cardita sp						x	
Cassianella decussata (Muenster)				x			
Chlamys acuteaurita (Schafhäutl)						x	
C. sp			x				
Coelostylina sp				x			
Cuspidaria gladius (Laube)			x				
Daonella sp							x
Dielasma sp					x		
Eucycloscala aff. *elegans* (Muenster)				x			
Fossariopsis binodosa (Muenster)				x			
Heterastridium conglobatum Reuss var. nov			x				
Hoernesia cf. *socialis* (Schlotheim)	x						
H. sp. cf. *H. sturi* (Wöhrmann)				x			
Homomya sublariana Krumbeck			x				
Indonautilus subbambanagensis Krumbeck			x				
Indopecten glabra Douglas			x				
I. seinaamensis (Krumbeck)			x				
I. subserraticosta (Krumbeck)			x				
Lozonema sp			x				
Lovcenipora vinassai Giattini					x		
Megalodon rostratiforme Krumbeck			x				
"*Monodonta*" aff. *supranodosa* Klipstein				x			
Montlivaltia norica Frech					x		
Myophoria seranensis Krumbeck			x				
M. verbeeki (Boettger)			x				
M. sp						x	
Naticella costata (Muenster)			x				
Neritaria cf. *mandelslohi* (Klipstein)				x			
N. transiens (Kittl)				x			
Neritopsis armata (Muenster) var. *cancellata* Kittl				x			
Opis laubei Bittner				x			
Ostrea cf. *montis cyprilis* Schafhäutl							x
O. sp						x	
Palaeocardita burica (G. Boehm, em. Krumbeck)			x				
Pinna cf. *tommasii* Wöhrmann and Koken			x				
Plagiostoma cf. *lineata* (Schlotheim)	x						
Promathildia aff. *bittneri* Kittl				x			
P. jenningsi Douglas				x			
P. trochleata (Muenster)			x				
Prospondylus cf. *comtus* (Goldfuss)	x						
Protocardia aff. *contusa* Healey			x				
P. proteus Krumbeck			x				
Pseudomonotis, similar to *P. clarai* (Emmrich)		x					
Rhynchonella sp					x		
Serania seranensis Krumbeck			x				
Spiriferina uncinata (Schafhäutl)					x		
Stephanocoenia schafhäutli (Winkler)					x		
Stylophyllopsis lindströmi (Frech)					x		
Temnotropis aff. *carinata* (Muenster)				x			
Terebratula (*Rhaetina*) *gregaria* Suess					x		
Terquemia aff. *cassiana* (Muenster)			x				
T. obliqua (Muenster)			x				
Thamnastraea alpina Winkler					x		

[*See references on page 39*]

TABLE 15.—*Triassic fossils from eastern Iran*—Continued

Name	1	2	3	4	5	6	7
T. rectilamellosa Winkler					x		
Thecosmilia (Calamophyllia) fenestrata Reuss					x		
T. (Calamophyllia) clathrata (Emmrich)					x		
T. cyathophylloides Frech					x		
Trachynerita aff. *depressa* (Hoernes)			x				
Undularia (Protorcula) subpunctata (Muenster)				x			
Velopecten albertii (Goldfuss)	x						
Worthenia coronata (Muenster)				x			

Localities of collections:

1. Shah 'Abdul 'Azim Mountains, southeast of Tehran (Krumbeck, 1922).
2. Shah 'Abdul 'Azim Mountains (Rivière, 1934a, p. 27).
3. Calcareous Upper Triassic sandstone from Naibandan, southeast-central Iran (Douglas, 1929, p. 628).
4. Grey Middle Triassic shale from Haus-i-Sheikh, near Naibandan (Douglas, 1929, p. 628).
5. Black Rhaetian limestone and shale at Haus-i-Khan, near Naibandan (Douglas, 1929, p. 628).
6. Rhaetian, west of the Heras and north of Imam-Zadeh-Hachim range (Krumbeck, 1922, table).
7. Khurasan (Krumbeck, 1922, table).

assic forms (R-84) from the Gulshan road 15 miles (24 km.) northwest from Duhak. Muller has verified Douglas' three subdivisions as Upper Triassic. Table 15 gives a list of the fossils from eastern Iran identified by various investigators.

Triassic rocks are also found in Iranian Armenia (Bonnet, 1912, p. 312) and Afghanistan (Hayden, 1911, p. 29). Douglas (1929, p. 630-631) points out certain paleogeographic paradoxes which might be inferred from comparison of the Iranian Triassic with that of Europe, western and central Asia, and the East Indies; he suggests an explanation in a possible partial breaking up of the continent of Gondwanaland into an archipelago during Triassic time.

JURASSIC SYSTEM

SUBDIVISIONS IN EASTERN IRAN

The Jurassic subdivisions recognized are named in Table 16.

LOWER JURASSIC (LIAS) SERIES

Lias was first mentioned, east of the village of Tash in the Elburz Mountains, by Göppert (1862, p. 17). A Jurassic shale "plant-bearing series" was early noted by Tietze (1879, p. 565) in the North. A similar "plant-bearing series," reported by Tipper (1921, p. 57), is widespread in the vicinity of Kerman and Ravar. The section, which conformably overlies earlier Liassic rocks, is noted:

Lias section near Ravar

3. Red grits with conglomerates; comparable in some ways with the "Saighan and red grit series" of north Afghanistan (Hayden, 1911, p. 34-35), considered by Professor Seward as being Middle Jurassic (Douglas, 1929, p. 625).

2. Green shales, grits, and conglomerates with plant remains.
1. Violet shales with limestone bands.

Douvillé described Middle and Upper Lias (De Morgan, vol. 3, pt. 2 of pt. 2, 1905, p. 200-203) in the Elburz Mountains, as being represented respectively by *Grammoceras normanianum* and *G. fallaciosum*. Schenck

TABLE 16.—*Jurassic system of eastern Iran*

American classification	European Subdivisions	Groups reported in eastern Iran
Upper Jurassic	Malm	Tithonian Kimmeridgian Oxfordian Callovian
Middle Jurassic	Dogger	Bathonian Bajocian
Lower Jurassic (= Lias)	Upper Lias	Toarcian
	Middle Lias	Pleinsbachian
	Lower Lias	(not known in Iran)

found *Posidonia* cf. *bronni* of Toarcian age 1500 feet (457 meters) southwest of Muzduran village in northeast Khurasan (S-3718). Although positive subdivisions were not generally made, Schenck considers the Lias of northeast Iran as being largely Toarcian. Lias was further described by Kühn (1938, p. 85-86), who summarized and commented upon earlier discoveries.

Rocks of generally nonmarine origin are widespread and in places apparently 3000 to 4000 feet thick; they consist of black micaceous sandstones, dark schistose shales, and some black quartzites cut by numerous quartz veins. These rocks are well stratified, contain plant remains, and weather brown or black. Lias is extensive (1) East of Meshed (Pl. 10, fig. 1), (2) in Elburz and Anti-Elburz areas, and (3) in desert areas from central Iran east to the Afghan border north of Lat. 33°. Certain Liassic fossils have been recently determined by Schenck from localities (1) 1½ miles (2.5 km.) west from Kalateh which lies N. 30° W. from Damghan (R-21); (2) 4 miles (6.5 km.) east from Kalateh (R-22); (3) Shah Kuh (pass) 10 miles (16 km.) west from Kalateh (R-24), and (4) 6 miles (10 km.) west from Jajarm (R-23).

Much farther south Liassic sandstone containing coal beds is reported by Furon (1936) from near Karkhouné, 51 miles (85 km.) by road northeast from Yezd, and also near Robat-i-Khan, near the 171-mile (276-km.)

point on the same road. Furon also found a lower Liassic limestone near Hadji-asad spring near the 202-mile (326-km.) point, and he reports sandstone and quartzite of this age 36 miles (60 km.) northeast from Gulshan. Upper Liassic limestones of marine origin were discovered by Tipper (1921, p. 55-59) in the Kerman area, and Schenck found Liassic plants between Kerman and Ravar. These strata are questionably present in the range south of Kashmar (formerly Turshiz) and likewise beneath the "volcanic series" near Firdows (formerly Tun).

Liassic coal is mined for local use in the vicinity of Meshed. Coal beds extensively mined at Abieck (near Kazvin) and Shamshak (north of Tehran) are, according to the literature, approximately of this age. Coal deposits near Nesa in the Karaj valley and those in the Lar, Nour, and Talar valleys of the Elburz will be important in the future. Coals of the central Elburz were described by Böehne (1932, p. 113-148). Many fossils, found in northeast Iran, substantiate the presence of Liassic strata (Table 17) in the areas mentioned.

MIDDLE AND UPPER JURASSIC SERIES

Principal features.—The Middle and Upper Jurassic series were both found in northern and central areas of eastern Iran. According to Reeves the section near Kalat-i-Nadiri (S-3728, S-3728A) is represented by about 5000 feet of oölitic limestones, calcareous shales, and pink limestones. Middle and Upper Jurassic are also widely represented in the Kuh-i-Hazar Masjid and Kuh-i-Binalud which are north and southwest of Meshed respectively, in the mountains west of Shahrud, in the vicinity of Kerman, and in the central Elburz Mountains north of Tehran. In central Iran undifferentiated Jurassic is reported 2 miles (3 km.) southwest from Aspak or 36 miles (58 km.) northeast from Gulshan (R-67). These series have been determined, among other localities, in outcrops 5 miles (8 km.) N. 30° E. from Morghzar, 18 miles (30 km.) northeast from Jajarm (R-27). Table 18 is a section in this locality as interpreted by Reeves.

Middle Jurassic series.—Rocks of Middle Jurassic age are known at many localities. Lower Bajocian was first mentioned by Douvillé (1904, p. 203-206) in the Elburz Mountains. Rivière found the series near Shah 'Abdul 'Azim about 5 miles (8 km.) south from Tehran. Bajocian and Bathonian fossils have been variously collected at localities listed in Table 19. The most up-to-date discussion of the faunal succession in the Iranian Bajocian is given by Spath (1936). Bajocian and Bathonian fossils, found by Messrs. R. C. Jennings and K. Washington Gray while

TABLE 17.—*Fossils from the Lias of eastern Iran*

Name	1	2	3	4	5	6	7	8	9	10
Alaria sp.			x							
Alothopteris whitbiensis									x	
Anomozamites minor Schimper	x									
Asplenium kosserti Heer	x									
Astarte excavata Sowerby						x	x			
A. sp.				x						
Baiera muensteriana Presl. var. *expansa* de Saporta	x									
Belemnites sp.			x			x				
Brachyphyllum sp.	x									
Cerithium sp.			x							
Comptopteris nilssonii									x	
Ctenis asplenioides Ettingsh.	x									
Ctenozamites cycadea Nathorst	x									
Cucullaea sp.						x				
Dioonites affinis Schenk	x									
Dumortieria radians (Reinecke)					x					
Goniomeris cf. *caudryi* Choffat			x							
Grammoceras costula (Reinecke)			x							
G. fallaciosum Bayle		x								
G. mactra Dumortier				x						
G. normanianum (d'Orbigny)		x								
G. sp.										x
Harpoceras aff. *radians* (Reinecke)							x			
H. aff. *serpentinum* (Reinecke)					x					
Hildoceras bifrons (Bruguière)		x								
Inoceramus polyplocus Roemer					x					
Lioceras acutum (Quenstedt)				x						
L. cf. *opalinum* (Reinecke)				x						
L. opalinum (Reinecke) var. *comptum* (Reinecke)				x	x					
Ludwigia murchisonae (Sowerby)		x								
Macrotaeniopteris gigantea Schenk	x									
M. vittata Germer	x									
"*Monotis*" *elegans* (Muenster)							x			
Myacites cf. *ferratus* Quenstedt							x			
Natica sp.		x								
Neuropteris sp.	x									
Nilssonia sternbergii (Nilsson)									x	
Oleandridium tenuinerve Schimper	x									
Palissya cf. *braunii* Endlicher	x									
Parkinsonia ? (*Reineckia* ?) sp.								x		
Pecopteris persica Schenk	x									
P. sp.	x									
Perten (*Chlamys*) aff. *ambiguus* Muenster					x					
P. lotharingicus Branco			x							
Pholadomya recticulata Agassiz			x	x						
P. voltzii (Agassiz)			x							
P. sp.					x					
Pleuromya cf. *elongata* (Munster in Goldfuss)			x							
Podozamites distans Presl.									x	
P. lanceolatus Heer	x									
Posidonia cf. *bronni* Goldfuss								x		
Protocardia sp.					x					
Pseudomonotis sp.			x							
Pterophyllum aequale Brongniart	x									
P. (*apichianum* or allied species)									x	

[See references on page 43]

TABLE 17.—*Fossils from the Lias of eastern Iran*—Continued

Name	1	2	3	4	5	6	7	8	9	10
P. braunianum Göppert	x									
Rhynchonella concinna Sowerby										x
R. plicatella Sowerby										x
R. sp.					x					
Stahlia persica Fischer			x							
Taeniopteris vittata Brongniart									x	
Terebratula eudesei Oppel										x
Trigonia literata Young and Bird		x								
T. producta Lycett		x								
T. striata Miller		x								
T. sp.							x			
Trochus sp.			x							
Variamussium pumilum (Lamarck)					x	x	x			
Walchia sp.		x								

Localities of collections:

1. Plant fossils (various collectors).
2. West of the Heras, north of the Imam-Zadeh-Hashim range (de Morgan).
3. Between Tehran and Firuzkuh (Stahl, determined by Fischer, 1915).
4. Diktasch, northeast of Samnan (Fischer, 1915).
5. East of Shah-Mirzad, near Pelvar (Fischer, 1915).
6. Near Foulad-mahale (Fischer, 1915).
7. Near Tazire, northeast of Damghan (Fischer, 1915).
8. Toarcian, about 1,650 feet (500 meters) southwest from village of Muzduran on southwest side of pass of same name (S-3718).
9. East of village of Tásh, in Elburz Mountains of Gurgan Province (Göppert, 1861, describes collection by Göbel).
10. Anti-Elburz ranges, just east of Doshan-tepeh, about 10 miles east of Tehran (Rivière, 1936, p. 278).
11. Elburz region (Krumbeck, 1922).

TABLE 18.—*Jurassic section near Jajarm*

Field Subdivision	Character	Feet
"Upper Jurassic"	6. Thin-bedded dove-colored to pinkish dolomite interbedded with calcareous clay shale; fossils rare and fragmentary	1200
	5. Grayish-white dolomite	500
	4. Thin-bedded pinkish dolomite with fossiliferous sandy dolomite in basal portion	800
"Lower Jurassic"	3. Light-green gypsiferous clay-shale and thin beds of calcareous	1500
	2. Dark-green shales and brown fossiliferous sandstone, richly fossiliferous	1200
	1. Ferruginous dark-brown shaly sandstone and greenish-gray gypsiferous shale, massive brownish-yellow limestone at base	800
	Total	6000

working for Anglo-Iranian Oil Company, were referred to by Douglas (1929) and confirmed by Cox (1936, p. 4). The species listed are:

Chlamys (*Radulopecten*) *tipperi* Cox (east of Ravar, 7 miles north from Rayin, east of Kerman, and at Hauz-i-Panj.
C. sp. (Hauz-i-Panj).
Ostrea (*Lopha*) cf. *gregarea* J. Sowerby; east of Ravar, and 7 miles north from Rayin.
O. sandalina Goldfuss (east of Ravar).

Upper Jurassic series.—Sandy limestones of probable Upper Jurassic age containing clavellate trigonias were first reported in eastern Iran by Douglas (1929, p. 627) from a place near Chehil-pai, about 24 miles

TABLE 19.—*Fossils from Middle Jurassic series in eastern Iran*

Name	1	2	3	4	5	6	7	8	9	10	11	12	13
Astarte opalina Quenstedt											x		
Belemnites, sp. of the *canaliculati* and *hastati* groups								x					
B. sp									x				x
Bigotites nocolescoi de Grossouvre							x						
Brasilia opalinoides (Mayer)													x
B. sp													x
Cadomites aff. *bigoti* Munier-Chalmas							x						
C. braikenridgii (d'Orbigny) (non Sowerby)							x						
C. rectilobatus Hauer							x						
Caeloceras extinctum Rollier						x							
Collyrites ringens (Agassiz)						x							
Cypricardia (*Pseudotrapezium*) aff. *franconia* Waagen		x											
Dactylioceras sp								x					
Euaptetoceras sp													x
Eudmetoceras cf. *eudmetum* (Buckman)													x
Graphoceras (*Ludwigella*) aff. *formosum* Buckman													x
Harpoceras sp. of the *falciferum* and *normanianum* groups								x					
Leioceras aff. *bifidatum* Buckman													x
L. cf. *comptum* (Reinecke)													x
L. cf. *lineatum* Buckman													x
L. cf. *opalinum* (Reinecke)													x
Lima sp										x			
Morphoceras dimorphum (d'Orbigny)						x							
M. polymorphum (d'Orbigny)						x							
Normannites linguiferus d'Orbigny		x				x							
Oecotraustes genicularis Waagen							x						
O. sp						x							
Oppelia aspidoides (Oppel)						x							
O. fusca (Quenstedt)						x							
O. intermedia Roemer						x							
O. aff. *notabilis* Roemer							x						
O. subradiata (Sowerby)							x						
Otoites aff. *contractus* (Sowerby)													x
Oxynoticeras sp								x					
Parkinsonia bigoti Nicolesco							x						
P. radiata Renz						x							
P. subarietis Wetzel							x						
P. sp. div						x							
Pecten anastomoplicus (Gemmellaro and Di Blasi)												x	

[See references on page 45]

TABLE 19.—*Fossils from Middle Jurassic series in eastern Iran*—Continued

Name	1	2	3	4	5	6	7	8	9	10	11	12	13
P. (*Chlamys*) aff. *ambiguus* Muenster			x										
P. (*Entolium*) *demissus* Phillips	x		x										
P. lens Sowerby									x				
P. sp.								x					
Perisphinctes (*Grossouvreia*) *auriggerus* (Oppel)							x						
P. aff. *castroi* Choffat												x	
P. cf. *colubrinus* (Reinecke) Quenstedt												x	
P. sp. cf. *fontannesi* Choffat												x	
P. inconditus Fontannes												x	
P. torresensis Choffat												x	
P. cf. *virgulatus* Quenstedt												x	
P. sp. div.						x							
Peronella cylindrica Goldfuss												x	
Pholadomya voltzii Agassiz		x											
P. sp.								x					
Phylloceras aff. *frederici-augusti* Pompeckj							x						
P. mediterraneum M. Neumann												x	
P. tortisulcatum Quenstedt *et al.*												x	
P. sp. div.						x							
Pinna cf. *lanceolata* Sowerby								x					
Plagiostoma ? sp.									x				
Planammatoceras sp.													x
Pleuromya urmiensis Borne					x								
Rhynchonella sparsicosta Oppel												x	
R. sp.								x					
Simoceras sp.												x	
Sonninia sowerbyi Mill. or *Witchellia laeviuscula* (Sowerby)		x	x										
Stepheoceras humphriesianum, or *Emileia sauzei* (d'Orbigny)			x	x									
S. subcoronatum (Oppel)							x						
S. sp.								x					
Terebratula dorsoplicata Suess							x						
Trigonia aff. *formosa* Lycett	x												
T. signata Agassiz				x									
T. sp.								x					
Waldheimia sp.									x				
Witchellia aff. *pavimentaria* (Buckman)													x
Fragments of *Belemnites*, Nautilae, Gastropodae, and Lamellibranchae							x						

Localities of collections:

1. Fulad-mahale (Stahl, determined by Fischer, 1915).
2. Between Tehran and Firuzkuh (Fischer, 1915).
3. Shah-Mirzad (Fischer, 1915).
4. Kelete and Ostaneck (Fischer, 1915).
5. Diktasch (Fischer, 1918).
6. Délitchai valley, below bridge of Khurasan road (Erni, 1931, p. 164-165).
7. Délitchai valley, below bridge of Khurasan road (Rivière, 1934a, p. 36).
8. Hills, 8½ miles (14 km.) southwest from Ravar (Tipper, 1921, p. 58-59).
9. Badamu, near Ravar (Fischer, 1915).
10. Near Mahun, same vicinity (Fischer, 1915).
11. Elburz region (Krumbeck, 1922).
12. Khurasan (Krumbeck, 1922).
13. Same as Loc. 8 (Spath, 1936).

TABLE 20.—*Fossils from lower part of Upper Jurassic*

Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Alectryonia sp																			x	
Aptychus laevis Meyer		x																		
"*A. lamellosus* Parkinson"		x																		
Cidaris sp											x									
Harpoceras sp				x																
Hecticoceras lugeoni de Tsytovitch								x												
H. lunuoides Kilian	x																			
Kosmoceras sp										x										
Lacunosella vistulica (Oppel)																x				
L. sp																	x			
Macrocephalites cf. *pila* Nikitin																				x
Montlivaltia sp																				x
Mytilus cf. *pectinatus* Sowerby																				x
Nerinea sp												x								
Ochetoceras canaliculatum (v. Buch)			x																	
O. cf. *hispidum* (Oppel)																	x			
Oppelia culmini Fontannes											x									
O. flexuosa (L. von Buch)		x																		
O. (*Neumayriceras*) sp																	x			
Perisphinctes alterneplicatus Waagen											x									
P. comptoni Pratt										x										
P. curvicosta (Oppel)			x																	
P. aff. *lucingensis*			x																	
P. mogosensis Choffat										x										
P. aff. *mogosensis* Choffat		x																		
P. morgani Fischer		x																		
P. peluricus Fischer		x																		
P. persicus Fischer					x															
P. poculum Leckenby			x																	
P. rhodanicus Dumortier				x																
P. rjasanensis Teiss					x															
P. stahli Fischer	x																			
P. subpatina Petitclerc							x													
P. subtilis Neumayr										x										
P. sp											x			x	x		x			x
Phylloceras aff. *antecedens* Pompeckj	x																			
P. firdusi Fischer									x											
P. hafisi Fischer									x											
P. sowerbyceras cf. *loryi* Munier-Chalmas														x						
P. aff. *tortisulcatum* Quenstedt																	x			
P. sp. of the group *tortisulcatum*	x																			
Reineckia cf. *anceps* (D'Orbigny)	x																			
R. brancoi Steinmann	x																			
R. douvillei Steinmann	x																			
R. cf. *greppini* Oppel					x															
R. multicostata Petitclerc						x														
R. nodosa Till	x																			
R. tilli Fischer	x																			
Rhynchonella lacunosa (Schlotheim)										x										
R. cf. *montoniana* D'Orbigny																	x			
R. aff. *spathi* Davidson												x								
R. aff. *suessi* Zittel												x								
R. cf. *triplicosa* (Quenstedt)	x																			
Septaliphoria cf. *moravica* (Uhlig)																x				
S. cf. *pinguis* (Roemer)																		x		

[See references on page 47]

TABLE 20.—*Fossils from lower part of Upper Jurassic*—Continued

Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
S. sp.													x							
Septocrurella sanctaeclarae (Roemer)																x				
Serpula sp.											x									
Sutneria sp.			x																	
Terebratula bicanaliculata (Schlotheim)																	x			
T. or *Zeilleria*												x								
T. sp.																			x	
Virgatosphinctes sp.																			x	

Localities of collections:

1. Callovian, in upper Heras valley, south of Pelour (Stahl, determined by Fischer, 1915; Rivière, 1934a, p. 37).
2. Oxfordian farther north, near Pelour, in light-colored limestones, referred to upper Oxfordian (Rivière, 1934a, p. 38).
3. Near Vahne (de Morgan, determined by Douvillé).
4. Lower Oxfordian limestones of Bend-i-Burida pass (Stahl, 1911; Rivière, 1934a, p. 38).
5. Upper Callovian, in Jumesar massif (Rivière, 1934a, p. 38).
6. Callovian, between Tehran and Firuzkuh (Rivière, 1934a, p. 38).
7. Callovian, west of Demavend (Rivière, 1934a, p. 38).
8. Oxfordian and Callovian, at Donb, in Talar valley (Rivière, 1934a, p. 38).
9. Callovian, at Kelete and Ostaneck (Stahl; Rivière, 1934a, p. 39).
10. Callovian, at Diktasch (Rivière, 1934a, p. 39).
11. Light-colored Oxfordian limestones at Nika and Ashraf (Rivière, 1934a, p. 39).
12. 2 kilometers below village of Acclimat and 11 miles (18 km.) west of Chinaran (R-39); Schenck considers these possibly Callovian.
13. 500 feet N. 60° E. from crest of Muzduran Pass (S-3728, determined by Muller).
14. 25 miles (40 km.) southeast from Meshed, near road to Serakhs (S-3729, determined by Muller).
15. 5 miles (8 km.) northeast from Kalateh (R-21B).
16. Oxfordian, from top of mountain about 5 miles (8 km.) east from Kalateh (R-22B, determined by Muller).
17. Oxfordian, 7 miles (11 km.) east from Morghzar (R-28, R-29, determined by Muller).
18. Lower Kimmeridgian, from one mile (2 km.) below village of Acclimat and 11 miles (18 km.) west from Chinaran (R-39, determined by Dr. Muir Wood).
19. Lower Tithonian or Bononian, from half a mile south of Gish and 15 miles (24 km.) north from Gulshan (R-62, determined by Muller).
20. From 10 miles (16 km.) northwest from Jukar and 8 miles (13 km.) N. 35° W. from a point on Yezd road 16 miles (24 km.) west from Gulshan (R-81, determined by Muller).

(39 km.) southwest from Naibandan. Oxfordian and Callovian fossils were given special attention by early geologists, although these rocks in Iran were at first included in the Middle Jurassic. De Morgan (Douvillé, p. 203-204) found Callovian, indicated by *Perisphinctes curvicosta*, and Oxfordian, indicated by *Ochetoceras canaliculatum*, in the Elburz Mountains. Schenck recently collected Upper Jurassic *Septaliphoroa* (sp. ?) 500 feet N. 70° E. from the crest of Muzduran Pass (S-3728). He also found Oxfordian or Kimmeridgian forms 25 miles (40 km.) southwest from Meshed (S-3729). Forms definitely of Oxfordian age were found (1) On the mountain top 5 miles (8 km.) east from Kalateh (R-22B) and (2) 4 miles (7 km.) east from Morghzar

AGE	FORMATION	THICKNESS IN FEET	LITHOLOGY	FOSSILS
Eocene	C	250	Well-bedded grayish white limestone forming high scarp	*Nummulites? Ostrea, Venericardia planicosta* (s.l.) *Cerithium*
Upper Cretaceous	D	380	Pink shale, reddish fine grained grits, and conglomerates	None
	E	600	250 calcareous shale and sandstone. 150 gypsiferous marine shale and ls. 300 light gray calcareous shale	*Turritella, Lopha*, rudistids, *Exogyra, Bryozoa Nerita Pontica*
	F	500	Sandstone, crossbedded in upper part	Bryozoa, rhynchonellids, *Ostrea*
Middle(?) Cretaceous	G	800	Calcareous sandstone and sandy shale	
Middle Cretaceous	μ^2	4300	2800 chalky clay shales weathering grayish white 1500 dark green gypsiferous clay shales.	*Inoceramus* (large) *Gryphaea*, Foraminifera, Ostracoda
	I	500	50 fossiliferous ls. 300 calcareous shale 150 feldspathic arkosic sandstone	*Trigonia* aff. *nodosa* Sow., *Exogyra, Ostrea.*
Lower Cretaceous	J' J^2	2500	1500 dark green clay shales 1000 light green calcareous shales with thin beds of limestone. Oolitic at base	"*Terebratula*" aff. *selia* Sow. *Pseudopygope Orbitolina*
	K	500	Red grits, arkosic sandstone, conglomeratic shale	None
Upper Jurassic	L	850	Oolitic limestone, massive gray limestone, calcareous shale	*Spondylopsis* sp. *Pterocerella* aff. *hudsella* Leym
Lias	M	2000+	Rhythmically-bedded black micaceous shale and sandstone	*Posidonia* cf. *bronni*

FIGURE 6.—*Composite geologic section through Muzduran Pass, Northeastern Iran*

By Amiranian Oil Company. Geology by Frank Reeves and B. F. Buie, fossils by H. G. Schenck.

(R-28, R-29). Rocks of Callovian age were found (1) 10 miles (16 km.) northwest from Jukar (B-3) and (2) 8 miles (13 km.) N. 35° W. from a point on the Yezd road 16 miles (26 km.) west from Gulshan.

Upper Oxfordian rocks seem to predominate in the Upper Jurassic of northeast Iran, with traces of Kimmeridgian inferred from the discovery of *Simoceras* aff. *venetiatum* Zittel in the Pelour district and *Peronidella* near Ashraf. Table 20 gives a list of the forms reported by various observers. Muller's determinations of the Upper Jurassic fossils collected by Amiranian Oil Company's geologists in northeastern Iran check those by Krumbeck (1922). Reeves reports the subdivisions of an Upper Jurassic section at Kalat-i-Nadiri:

Section at Kalat-i-Nadiri	Feet
3. Black and brown limestone	1000
2. Dark fissile calcareous shale	2000
1. Brown to gray limestone	2000
Total thickness observed	5000

Base not reported.

In the Muzduran Pass section (Fig. 5) the total Jurassic thickness consists of about 850 feet of oölitic limestone, calcareous shale, and pink limestone, as opposed to 4000 feet at a point 40 miles (64 km.) northeast from Meshed and 4000 and 7000 feet elsewhere. In the mountain belt, bordering the valley between Meshed and Quchan, the Upper Jurassic appears to be composed of 3000 to 4000 feet of massive, buff, fossiliferous limestones. The series was recognized in outcrops northeast of Kalateh and again northeast of Jajarm and east of Morghzar.

South of the Elburz Mountains the Upper Jurassic series was discovered half a mile south from Gish and 15 miles (24 km.) north from Gulshan (R-62). The rocks were also found in outcrops 22 miles (35 km.) S. 15° W. from Jandaq and 3 miles (5 km.) northwest from Seruman (R-139, R-140). It is also present in the Anti-Elburz mountains east of Tehran (Rivière, 1906, p. 279-280). Table 21 gives a list of fossils from the Upper Oxfordian of Iran.

Rivière (1934a, p. 44) states that existence of the Portlandian is probable because of the discovery of *Berriasella calisto* d'Orbigny in the south-central Elburz.

CRETACEOUS SYSTEM

PRINCIPAL FEATURES

Distribution and relationships.—Rocks of Cretaceous age (Pl. 6), resting with a general but not continuous unconformity upon the Lias or Middle or Upper Jurassic rocks, are distributed through eastern Iran. Where the Lias is missing the Cretaceous unconformably overlies still

older rocks. As a matter of fact, there are several unconformities within the Cretaceous. Rivière (1936, p. 281-282) discovered an angular discordance between Lower and Middle Cretaceous strata in the Anti-Elburz mountains just east of Tehran. Reeves reports 4000 to 4500 feet of Upper

TABLE 21.—*Oxfordian fossils from northeast Iran*

Name	1	2	3	4	5	6	7	8
Aspidoceras oegir (Oppel)	x							
Cylindrophyma sp.	x							
Montlivaultia sp.	x							
Nerinea sp.							x	
Neumayria flexuosa (Favre)	x							
Ochetoceras canaliculatum (von Buch)		x						
Perisphinctes achilles (d'Orbigny)				x	x			
P. (*Ataxoceras*) *lothari Loriol*						x		
P. aff. *mindowe* Siemiradski						x		
P. aff. *polyplocus* (Reinecke)				x	x			
P. cf. *subrota* Choffat			x					
Rhynchonella corallina (Leymerie)								x
Undetermined brachiopods							x	

Localities of collections:

1. Limestones at Ashraf (Rivière, 1934a, p. 43-44).
2. Between Imam-Zadeh-Hashim and Emaret, Heras valley (Stahl, 1911, p. 13).
3. Doab, in Talar valley (Rivière, 1934a, p. 43-44).
4. Limestones at Aineversan (Rivière, 1934a, p. 43-44).
5. Limestone massif west of Demavend (Rivière, 1934a, p. 43-44).
6. Oxfordian, 4 miles (7 km.) east from Morghzar (R-28), identified by Muller.
7. Probable Oxfordian, 6 miles (10 km.) southwest from Jajarm (R-30).
8. Anti-Elburz range east of Doshan-tepeh, east of Tehran (Rivière, 1936, p. 279).

Cretaceous, consisting of well-bedded buff to pinkish cherty limestones and light-green chalky clay shales, resting unconformably on Lower Cretaceous limestones in the Khur region, although he finds "no probable discordance" with Upper Jurassic rocks in that vicinity or at Kalat-i-Nadiri (Pl. 2). Schenck found the Aptian unconformable on metamorphic rocks between Pusht-i-Badam and Rizab (S-3733, S-3756 and S-3757) and he also suspects an unconformity at the top of the Upper Cretaceous "red beds." On the main north-south highway at a point 27 miles (43 km.) southeast from Gunabad the Cretaceous beds rest unconformably on "Lias" shales.

Cretaceous species were first collected by De Hell and determined by De Verneuil (Viquesnel, p. 503) from a village reported as "Ieni-Hissar," near Radkan in the Nika valley of the north-central Elburz. Numerous forms have since been collected in the Elburz region and in Khurasan. Since numerous Cretaceous areas are known in Afghanistan and British Baluchistan there is no doubt that the subsurface extent of these rocks in eastern Iran is likewise great. According to stratigraphic measure-

TABLE 22.—*Cretaceous system in eastern Iran* *

American series	European Subdivisions			Maximum known thickness (Feet)	Observed character
Upper Cretaceous	Upper Cretaceous	Danian		380	Pink shale, red sandstone, and conglomerate
		Maestrichtian		600	Limestone and calcareous shale
		Senonian	Campanian		
			Santonian	500	Buff calcareous sandstones; cross-bedded in upper part
			Coniacian		
	Middle Cretaceous	Turonian		800	Calcareous sandstone and sandy shale
				2300	Chalky clay-shales, weathering grayish white
				1500	Dark-green gypsiferous clay-shales
		Cenomanian		400	Calcareous shale and fossiliferous limestone
				100	Glauconitic sandstone
Lower Cretaceous	Albian			1500	Dark green-gray shale
	Aptian			1000	Light-green calcareous shale with thin limestone beds—oölitic at base
	Local unconformity				
	Barremian			4000	Red arkosic sandstone, conglomerate, and shale; 500 feet thick in the Muzduran Pass region, grading westward into 4000 feet of sandy beds, limestones, and green shales
	Hauteverian				
	Valanginian				
	Infra-Valanginian				
Total composite thickness.....				13,580	

* The section above the Cenomanian is taken mainly from measurements made northeast of Muzduran Pass in northeast Khurasan. The lower part of the section is composite from other areas. Hence, the aggregate thickness outlined may be somewhat greater than that actually found in any single locality. The Muzduran Pass section itself is about 10,000 feet thick (Fig. 6).

ments made by Reeves and paleontologic determinations by Schenck, the Cretaceous system, more than 10,000 feet thick over wide areas, is susceptible to subdivision as recorded in Table 22.

Areas north of Elburz Mountains.—The Cretaceous system outcrops extensively north of the Kuh-i-Hazar Masjid in extreme northeast Iran, thence continuously southeast to the Afghan frontier between Pul-i-Khvatun and Kahriz. Collections have been made at localities (1) 26 miles (43 km.) by road southeast from Maraveh-tepeh (S-3710, T-128) and (2) at the southern foot of Allah-Akbar pass (S-3716, T-103) between Dachit and Muhammedabad, on the road from Quchan to Lutfabad. Other Cretaceous areas are described by Thompson in northwest Khurasan and westward into northeast Gurgan.

Collections (R-34 to R-38) which are broadly Aptian to Cenomanian in age have been identified from certain localities 10 to 15 miles (16 and 24 km.) northwest to west-northwest from Bujnurd or 5 miles (8 km.) southwest from Besh-Khardesh in a limestone ridge just west of the highway, and again 25 miles (42 km.) north from Quchan on the road to Deredges. A similar collection was made half a mile (1 km.) south of Col-Natu (R-50) and (2) 6 miles (10 km.) north from Maraveh-tepeh. *Acanthoplites* sp., of uppermost Aptian or lowermost Albian age, was, according to Muller, found at a spot 6 miles (10 km.) north from Maraveh-tepeh (T-13).

Areas south of Elburz Mountains.—South of the mountains some of the higher hills between Maiamai and Maluman consist of Cretaceous limestone as much as 4000 feet thick. A thickness of 2500 feet of buff, massive limestone is said by Reeves to form mountain ranges between Shahrud and Turut. Below these beds lies 1500 feet of "thin-bedded, grey, pink, and black fossiliferous limestone, bearing Foraminifera, *Terebratula, Ostrea,* and *Alectryonia.*" The series was determined at (1) Chah-i-Chirin, 30 miles (48 km.) S. 70° E. from Samnan (R-118) and (2) a point 4 miles (6.5 km.) east from Chah-i-Chirin (R-119). Cretaceous areas are mapped near Jandaq and Khur. Determinations of Cretaceous limestone with *Praesorites* (?), *Exogyra,* and *Pedalion,* reported to lie 100 feet above metamorphic rocks, were made from a locality 2 miles (3 km.) S. 47° W. from Saghand (caravanserai) and 65 miles (104 km.) northeast from Yezd (S-3755). Oölitic limestones with *Orbitolina* were found 100 feet above metamorphic rocks (S-3756) about 2½ miles (4 km.) N. 20° W. from Pusht-i-Badam and 45 miles (72 km.) southeast from Khur. Again, the Cretaceous was determined in localities (1) 22 miles (35 km.) S. 15° W. from Jandaq and 5 miles (8 km.) northwest from Seruman (R-141, R-142), and (2) 4 miles (6.5 km.) southwest from Khur (R-148, R-149).

South-central area.—The Cretaceous rocks in south-central Iran are most commonly massive pink to white "Hippurite limestones," having

TABLE 23.—*Cretaceous section near Kerman*

No.	Character	Feet
8.	"Hippurite limestone", mostly pale in color	2000
7.	Sandstones, shales, and dark limestones	3000
6.	Dark and pale-gray limestone with *Hippurites*	500
5.	Pale limestone	200 ?
4.	Conglomerate, very calcareous	600
3.	Pale limestone with *Hippurites*	1500
2.	Dark compact limestone with *Hippurites*	600
1.	Dark flaggy limestone (no *Hippurites*)	600
	Total	9000 ?

TABLE 24.—*Incomplete Cretaceous section near Isfahan*

No.	Character	Fossils	Feet
17	Dense blue-gray limestone	*Orbitolina*	7
16	Dense limestones	*Terebratula* aff. *sella*, rare *Orbitolina*	10
15	Dense blue-gray limestone	Rare *Orbitolina;* dense "oyster reef" at top	5
14	Hard limestone	*Orbitolina*	10
13	Sandy limestone, well-bedded	*Orbitolina*	13
12	Massive dark limestone	*Orbitolina*, echini	6
11	Dark to buff limestone	*Orbitolina*, echini, gastropods, and pelecypods	16
10	Dense blue-gray limestone		10
9	Dark sandy limestone	*Orbitolina*, etc	12
8	Massive, dense bluish-gray limestone		14
7	Buff-weathering limestone and interbedded dark sandy limestone	*Orbitolina, Exogyra, Terebratula*	17
6	Dark sandy limestone		4
5	Buff limestone, jointed, gray on fresh fracture		5
4	Platy gray limestone		8
3	Dark sandy limestone	*Orbitolina, Terebratula,* ostreid pelecypods, etc	10
2	Buff-weathering limestone		18
1	Red, sandy limestone unconformably above Liassic (?) beds		10
	Total		175

conchoidal fractures, and were called by Pilgrim "Middle Cretaceous"; other limestones and shales also rest unconformably on the "Jurassic plant-bearing series." In addition to *Hippurites* there are, according to Tipper (1921, p. 60), *Sphaerulites* with *Nerinea, Actaeonella, Trigonia, Pecten quinquecostata* Sowerby, *Exogyra* aff. *E. columba,* and *Ostrea* sp. Stahl (1897) mapped Cretaceous rocks in the centers of apparent anti-

clines trending north-south near Bafq and Ravar. De Böckh, Lees, and Richardson (1929, p. 128) mention Cretaceous fossils in the Yezd-Isfahan region. Cox (1936, p. 5), in referring to Pilgrim (1924, p. 24), mentions the occurrence of *Trochactaeon* cf. *giganteus* (J. de C. Sowerby) in "Hippurite limestone" at Badamu, 14 miles (23 km.) north from Kerman. Blanford (1876, p. 487-95) reported a partial section (Table 23) which he considered Cretaceous in the vicinity of Kerman.

The section shown in Table 24 was measured by Schenck in Cretaceous rocks overlying probable Liassic beds in a mountain near Shahristanak 8 miles (13 km.) by road S. 66° E. from Isfahan (S-3741).

In the extreme eastern belt of Iran Cretaceous limestones bearing rudistids and *Orbitolina* form conspicuous hills and mountain ridges above the surrounding deserts. Near the north-south highway in extreme eastern Iran the Cretaceous crops out in anticlines. Notably, a collection from 40 miles (64 km.) S. 80° W. from Sefid-abeh (R-107) proved to be of this age. Elsewhere variegated gypsiferous clay-shales and some volcanic rocks appear to intervene between the Lias and the Cretaceous; however, the wide-spread faulting may account for this apparent relationship.

LOWER CRETACEOUS SERIES

Lithologically the Iranian Cretaceous was generally subdivided into two divisions—limestones predominating in the lower one, which embraces Lower and Middle Cretaceous rocks up to Cenomanian, marlstones predominating in the upper division which comprises Senonian and Maestrichtian. In northwest Khurasan the following partial sections of Lower Cretaceous rocks were recently reported:

1.—Aitamir to Maraveh-tepeh
(Thompson and others)

	Feet
White to light-buff, dense, thin-bedded limestone	1300
Unconformity	

2.—Garm-ab, 21 miles (34 km.) southeast from Maraveh-tepeh
(Thompson and others)

Massive limestone (same as in pl. 6)	600+

3.—Between Robat and Bujnurd
(Thompson and others)

2. Grayish-white massive limestone	600
1. Dense light-gray to light-tan limestone	1100
Total	1700
Unconformity	

4.—Kalat-i-Nadiri
(Reeves and Buie)

Brown and black limestone, and red to green calcareous shale	500

5.—Muzduran Pass
(Reeves and Buie)

Red arkosic sandstone, conglomerate, and shale	500

Unconformity

6.—Khur area
(Reeves)

4. Black thin-bedded sandy limestone carrying orbitoids of Aptian age	1000
3. Green calcareous clay and brown limestone	500
2. Pinkish calcareous sandy clay	1000
1. Alternating (2-5 feet thick) limestones and pink calcareous clay	500
Total	3000

Unconformity

Paleontologic evidences of Lower Cretaceous rocks are widespread. Dietrich (1927, p. 450) mentioned *Orbitolina lenticularis* Bl. (collected by Hedin, loc. 14) from the Lower Cretaceous beds 112 miles (180 km.) southeast from Tehran, and Cretaceous rocks containing *Requienia* were determined by Fischer (De Böckh, Lees, and Richardson, 1929, p. 139) from the Shir Kuh near Yezd. Rivière (1906, p. 279-280), in the Anti-Elburz ranges east of Tehran, mapped Lower Cretaceous rocks consisting of brown, gray, or yellowish limestones, foraminiferal limestone, and conglomerates.

Considerable progress has been made in subdividing the Lower Cretaceous, for Albian beds (Vraconian) were inferred by Douvillé (1904, p. 541-542, 552) owing to the presence of *Praeradiolites davidsoni* and *Orbitolina* in northern Iran and of *Puzosia denisoni* and *Turrilites bergeri* in the southwest. Krumbeck (1922) recorded the presence of Hauteverian fossils in the Elburz region and mentions numerous Barremian and Albian forms from Khurasan. The presence of Barremian was assumed by Rivière (Pfender, 1938, p. 235) in the Sepaich range of the Anti-Elburz east of Tehran following identification of marine calcareous algae there. Table 25 gives the principal fossil discoveries in the Lower Cretaceous.

Lower Cretaceous was identified in north-central areas: (1) 25 miles (40 km.) S. 15° E. from Damghan (R-80A), (2) 25 miles N. 60° E. from Turut (R-82A, R-82B), (3) 40 miles (64 km.) N. 60° E. from Samnan (R-83A), and (4) 14 miles (19 km.) N. 50° E. from Khur (R-143). Aptian fossils were identified by Schenck and Muller in light-green calcareous shale with thin beds of limestone, oölitic at the base, collected 1 mile north of Muzduran Pass in extreme northeast Iran (R-41, S-3718). Among the fossils are *Terebratula* aff. *sella* Sowerby, *T. pyrina* (?), and *Orbitolina* aff. *lenticularis*.

MIDDLE CRETACEOUS SERIES

For convenience of discussion the Middle Cretaceous is here considered as a separate division including the Cenomanian and Turonian groups of

TABLE 25.—*Fossils from Lower Cretaceous series in northeast Iran*

Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Acanthodiscus cf. *vaceki* Neumayr and Uhlig	x																	
Acanthoplites aff. *aschilatensis* Anthula																	x	
"*Arca*" cf. *carinata* Sowerby														x				
Astarte sp														x				
Cyprina sp														x				
Eoradiolites aff. *davidsoni* (Hill)		x	x															
Exogyra sp								x										
Heteraster cf. *oblongus* Agassiz									x	x								
Hinnites sp							x											
Hoplites of the group *Cryptoceras* d'Orbigny	x																	
"*Leda*" sp														x				
"*Modiola*" sp														x				
Neithea cf. *morrisi* Pictet and Renevier												x						x
Orbitolinae of the group *Orbitolina subconcava*		x																
Orbitolina sp						x	x	x	x	x	x					x		
Parahoplites sp							x	x			x	x				x		
Perisphinctes sp	x																	
Perna sp														x				
Pinna sp						x												
Pliotoxaster cf. *collegnoi* (d'Orbigny)							x		x		x				x			
P. sp								x										
Pseudidaminae sp												x						
Pseudopyrina sp									x									
Requienia ammonia (Goldfuss)				x														
Rhynchonella depressa (Sowerby) d'Orbigny					x									x				
R. aff. *lata* (Sowerby)							x											
R. multiformis (Roemer)										x								
R. multiformis var. *ardescita* Jacob and Fallet					x													
R. multiformis var. *contractoides* Jacob and Fallet												x						
R. sp						x		x			x							
Terebratula biplicata Sowerby														x				
T. aff. *collinaria* d'Orbigny					x								x					
T. aff. *sella* Sowerby							x			x								
Toxaster oblongus Deluc									x	x								
T. recordeanus Cotteau											x							
Trigonia aliformis Parkinson														x				
T. cf. *daedalaea* Parkinson														x				
T. cf. *rudis* Parkinson														x				

Localities of collections:

1. Village of Hassangar, at confluence of Lar and Upper Karaj valleys (Stahl, 1911, p. 14; (Rivière, 1934a, p. 47).
2. Bend-i-Burida pass, in black Albian limestones (Douvillé, 1904, p. 208; Rivière, 1934a, p. 47).
3. Near Emaret, farther north (Rivière, 1934a, p. 47).
4. Between Firuzkuh and Babol (formerly Barfarush), in light-colored Barremian limestones (Rivière, 1934a, p. 47).
5. Sepaich Mountain in Anti-Elburz range, directly east from Tehran, in brown-gray Hauterivian limestones (Rivière, 1936, p. 280).
6. On road to Deredges, 26 miles (42 km.) north from Quchan (R-38); probably Aptian (Schenck correlates approximately with S-3719, S-3716, S-3712, R-36, R-37).
7. 6 miles (10 km.) northwest from Bujnurd (S-3713); Aptian.
8. Aptian, 10½ miles (17 km.) southwest from Bujnurd at village of Merou (S-3711).
9. 1¾ miles (2.8 km.) east from junction of Askhabad and Lutfabad roads on road from Quchan; Aptian (S-3717=T-106).
10. Aptian, 11 miles (18 km.) north from Quchan (T-2).
11. Merou, 4½ miles (7 km.) from Badaralu and 4½ miles west from Bujnurd on road to Shahabad; Aptian (S-3712).

(Continued at bottom of next page)

rocks. Among the Middle Cretaceous sections recently recorded are a few notable ones:

1.—Robat-Bujnurd section
(Thompson and others)

	Feet
5. Dark-olive calcareous shale; occasional thin beds of coarse dark limestone	250
4. Light bluish-gray calcareous silts, fine-grained sandstone, sandy limestone; S-3712 and S-3713 report *Orbitolina, Epiaster, Exogyra, Parahoplites, Rhynchonella* aff. *lata* (Sowerby), *Terebratula* cf. *sella* Sowerby, *Hinnites, Heteraster* (?)	3500
3. Gray-green to dark-lavender calcareous shale	1500
2. Coarse, dark-gray limestone, some calcareous shale, arenaceous in lower beds	1200
Total	6450

1. Rests on Lower Cretaceous rocks.

2.—Kalat-i-Nadiri section
(Reeves and Buie)

5. Gray, fine-grained calcareous sandstone	1000
4. Light-gray calcareous shale	3000
3. Greenish calcareous sandstone	500
2. Gray-green calcareous shale	2000
Total	6500

1. Rests on Lower Cretaceous rocks.

3.—Muzduran-Serakhs section
(Reeves and Buie)

4. Calcareous sandstone and sandy shale	800
3. Chalky clay-shales weathering greenish-white (Schenck identified *Gryphaea*(?), Foraminifera, and ostracodes from R-43)	2300
2. Dark-green gypsiferous clay-shales (yielded *Inoceramus* in S-3726)	1500
1. Dark-green clay shale	1500
Total	6100

Cenomanian beds were noted by Krumbeck (1922), and fossils of this age were recently identified above recognized Aptian outcrops (R-42, S-3727) 2 miles (3 km.) north from Muzduran Pass. Turonian fossils, earlier reported by Krumbeck (1922), were found (R-43) in sequence 2½ miles (4 km.) north from the same pass. About 2500 feet stratigraphically above the base of the Middle Cretaceous are two or more very persistent glauconitic sandstone beds carrying *Trigonia* and

12. Probable Aptian, from Besh-Khardesh shrine, 5 miles (8 km.) southwest from Bujnurd (R-34, S-3713).
13. Elburz region (Krumbeck, 1922).
14. Khurasan (Krumbeck, 1922).
15. 9 miles (15 km.) N. 70° W. from Bujnurd; 1 km. north from road.
16. Upper Aptian or Lower Albian from 5 miles (8 km.) southwest from Besh-Khardesh (R-37, S-3716).
17. Uppermost Aptian or lowermost Albian, from Kara-bair Dagh, 6 miles (10 km.) north from Maraveh-tepeh (T-13, determined by Muller).
18. Aptian, near base of section near Shahristanek in first conspicuous mountain S. 66° E. from Maidan-i-Shah in Isfahan, on east side of Zinda Rud, 8 miles (13 km.) by road from north end of Ala Verdi Bridge (S-3741A).

TABLE 26.—*Upper Cretaceous fossils from eastern Iran*

Name	1	2	3	4	5	6	7	8	9
Alectryonia "carinata" (Lamarck)								x	
Beisselina sp						x			
Bulimina sp			x						
Chlamys cf. *asper* (Lamarck)								x	
Corax appendiculatus Agassiz	x								
Cucullaea sp	x								
Enallaster sp								x	
Exogyra cf. *columba* (Lamarck)		x				x			
E. sp				x					
Globigerina cf. *bulloides* d'Orbigny									x
G. sp			x			x			
Gyroidina sp			x						
Hippurites gosaviensis Douvillé					x				
Inoceramus cf. *striatus* Mantell	x								
I. (*Volviceramus*) cf. *lamarcki* Parkinson (*I. brongniarti* Sowerby)							x		
Janira (*Neithea*) *quadricostata* (Sowerby)		x							
Nodosaria sp			x						
Ostrea sp	x								
Pecten cf. *ternatus* Münster sp							x		
P. sp					x				
Pectunculus sp	x								
Pironaea persica (Vredenburg)					x				
Plagioptychus sp					x				
Ptychodus cf. *mamillatus* Ag	x								
Pygurus sp								x	
Pyropsis sp	x								
Rosalina linneiana d'Orbigny						x			
Tellina sp	x								
Trigonia aff. *nodosa* Sowerby				x					
Turritella sp	x								
Venus sp	x								
Vincularia sp						x			
Virgulina sp			x						

Localities of collections:

1. Nika valley, south of Ashraf, in glauconitic marl resting on phyllitic clay (Rivière, 1934a, p. 50).
2. Left bank of Nika Rud in gray limestone (Stahl, 1911, p. 15).
3. 2 miles (3.2 km.) northwest from summit of Muzduran Pass on road to Serakhs (S-3725).
4. One mile (1.6 km.) northwest by road from summit of Muzduran Pass, in glauconitic sandstone, 2,500 feet stratigraphically above lower Cretaceous red grits (S-3727).
5. Upper Turonian or lowermost Senonian on Kuh-i-Nahrahu and Kuh-i-Siah on the Afghan border northwest of Lake Helmund (Vredenburg, 1909, p. 221-219).
6. Anti-Elburz Mountains, 10 miles (16 km.) east of Tehran (Rivière, 1906, p. 281-282).
7. Elburz region (Krumbeck, 1922).
8. Khurasan (Krumbeck, 1922).
9. Hedin's loc. 52, 12 miles (20 km.) south from Turut (Dietrich, 1927).

Exogyra species. Rivière (1936, p. 281-282) reports Middle Cretaceous forms in the Anti-Elburz ranges just east of Tehran. De Böckh, Lees, and Richardson (1929, p. 139) mention Cenomanian and Turonian fossils from Anarek. A collection of Cenomanian *Radiolites* cf. *choffati* was recently made 4 miles (6.5 km.) southwest from Khur (R-149). Table 26 gives a list of the Middle Cretaceous forms reported in eastern Iran.

UPPER CRETACEOUS SERIES

The Upper Cretaceous, likewise, is widespread in eastern Iran. A number of sections, Senonian to Danian inclusive, as defined for present use, have been measured or reported in northern Khurasan:

1. Aitamir-Maraveh-tepeh section
(Thompson and others)

	Feet
2. Dark-green, fine-grained, thin-bedded glauconitic sandstone (T-20, H-25 to H-29)	1000
1. Rests on Middle Cretaceous rocks.	

2.—Garm-ab section
(Thompson and others)

3. Bright red silts with occasional thin beds of fine-grained glauconitic sandstone	75
2. Dark-brown, coarse-grained arenaceous limestones	50
Total	125
1. Rests on Middle Cretaceous rocks.	

3.—Robat-Bujnurd section
(Thompson and others)

5. Bright red silt with occasional thin beds of glauconitic sandstone	600
4. Coarse, dark-brown sandstone, more or less calcareous, sometimes cross-bedded	25
3. Bluish-green, thin-bedded, fine-grained calcareous sandstone	250
2. Light-buff, fine-grained arenaceous limestone	70
Total	945
1. Rests on Middle Cretaceous rocks.	

4.—Kalat-i-Nadiri section
(Reeves and Buie)

4. Variegated shale	250
3. Calcareous shale	1000
2. Buff arenaceous limestone	500
Total	1750
1. Rests on Middle Cretaceous rocks.	

5.—Muzduran Pass section
(Reeves and Buie)

4. Pink shale, red sandstone, and conglomerate	380
3. Limestone and calcareous shale	600
2. Calcareous buff sandstone, cross-bedded in upper part	500
Total	1480
1. Rests on Middle Cretaceous rocks.	

More definitely the Lower Senonian was determined above Turonian outcrops in a gorge (R-44) northeast of Muzduran Pass and 6 miles (10 km.) southwest from Surukhs[6] (Pl. 6). In a bluff on Hari Rud Upper Senonian, originally proved in Khurasan by Khumbeck (1922), was recently confirmed 5 miles (8 km.) east from Janet-abad (R-48). Muller has determined the existence of Maestrichtian in (1) The mountain belt northeast of Muzduran Pass (S-3720X), (2) a locality 9 miles

[6] This place should not be confused with Serakhs, situated 25 miles (40 km.) to the northeast.

(15 km.) S. 45° E. from Talhap (position unknown), and (3) Maestrichtian or Danian at localities respectively 8 miles (13 km.) north (R-144) and (4) 15 miles (24 km.) north (R-145) from Khur.

Farther west the series was determined at (T-145) 21 miles (34 km.) southwest from Maraveh-tepeh on the road to Gurgan. In an inter-

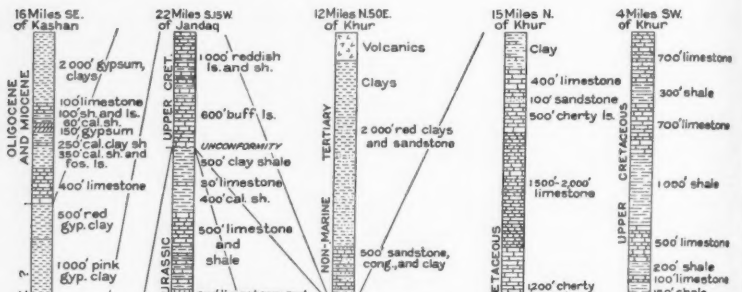

FIGURE 7.—*Variations in columnar section in north-central Iran*
By Amiranian Oil Company. Geology by Frank Reeves and others.

mediate position in the northern belt a "large Upper Cretaceous *Inoceramus*" was found 130 feet stratigraphically below "numerous oysters" (T-352, S-3714) in an outcrop 1½ miles (2.4 km.) south of the village of Gurudarband, which lies north of the Atrek River on the road from Bujnurd to Robat.

The Upper Cretaceous series was found in southeast-central Iran in a locality (R-116) 3 miles (5 km.) N. 60° W. from Murkh-i-Surkh. In north-central Iran Upper Cretaceous was similarly proven (1) 22 miles (35 km.) S. 15° W. from Jandaq and 3 miles (5 km.) northwest from Seruman (R-141), (2) 3 miles (5 km.) S. 45° W. from Arasun (R-148),[7]

[7] Although this collection was considered by Reeves as "Upper Cretaceous" Schenck merely remarks that the fossils are "probably Cenomanian or younger."

and (3) 8 to 15 miles (15 to 24 km.) north and (4) again 4 miles (6.5 km.) southwest from Khur (R-149); its absence from some areas of north-central Iran is notable, however, as is illustrated in the middle section of Figure 7. The Upper Cretaceous interpretations have lately been checked and added to by Muller. Professor Schenck has in preparation a paper on pelecypods going under the name of *Venericardia beaumonti* (d'Archiac and Haime) from 5 miles S. 60° E. of Murkh-i-Surkh. The occurrence and stratigraphic significance of this form have been summarized by Rutsch (1936). The beds at locality (R-115) are believed to be Maestrichtian in age. Future work may demonstrate that in eastern Iran, as in British Baluchistan (Noetling, 1903), there is a transition from Cretaceous to Eocene. Table 27 gives a list of determined fossils from known localities.

CRETACEOUS "VOLCANIC SERIES"

Some volcanic activity took place in the south-central region during Cretaceous time. Blanford (1876, p. 479) called attention to the evidence of such outbursts at Abariq near Kerman and correlated them with late Cretaceous activity in the Caucasus. Tipper (1921, p. 61-63) reported a great thickness of lavas, tuffs, and agglomerates resting unconformably on "Hippuritic limestone" in the range north of Iranshahr. In the same area he noted a number of porphyritic dikes, the outcrop of which was said to aggregate 25 miles (40 km.) in breadth. Blanford reported Upper Cretaceous (in part) rhyolitic and veined tuffs near Bam, "stained red and crowded with iron ores." He suggests that these volcanic rocks may be identical in age with Vredenburg's (1901, p. 195-197) tuffs and agglomerates on the Baluchistan frontier, which he considered unconformable below the Kuh-i-Sultan and Kuh-i-Taftan lavas.

TERTIARY SYSTEM

EOCENE AND OLIGOCENE SERIES

Principal features.—Eocene deposits of eastern Iran, although widespread, are confined mainly to synclinal troughs. A practically continuous belt of Tertiary basins, interrupted by belts of uplifted Eocene and older sediments, covers much of the northern Kavir and extends west to the vicinity of Qum and Kashan.

Numerous fossil collections have been made. *Nummulites* were collected at a very early date by De Hell and determined by De Verneuil (Viquesnel, 1850, p. 506-509) from a locality near Radkan in the Nika valley in eastern Mazandaran, and likewise from "Khialanek pass." Blanford (1876, p. 472-480) reported *Nummulites* (sp. allied to *N. lyelli* d'Archiac and Haime), *N. vicaryi* d'Archiac and Haime, and *Assilina*

TABLE 27.—*Upper Cretaceous fossils from eastern Iran*

Name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Actaeonina cf. *doliolus* Muller				x													
Alectryonia aff. *arizpensi* Böse					x												
Amussium cf. *sulcatellum* Stoliczka					x												
A. virgatum (Nilsson)					x												
Anomalina sp		x															
Aporrhais cf. *seculifera* Forbes				x													
? *Biradiolites persicus* Douvillé							x										
Briassopneustes sp						x											
Bullina alternata (d'Orbigny)				x													
Catopygus or *Oolopygus*						x											
Cerithium aff. *engelades* Coquand											x						
Coraster aff. *vilanovae* Seunes																x	x
Cristellaria sp					x												
Cyclaster aff. *integer* Seunes																x	
Cyclolites sp			x														
Cypris sp					x												
Ditremaster sp														x			
Echinocorys cf. "*Jarenia*" *pyrenaica* Seunes																x	
E. scutatus Leske															x		
E. aff. *sulcatus* d'Orbigny													x	x		x	
Epiaster sp	x																
Euspira pagoda (Forbes)				x													
E. rotundata (Sowerby)				x													
Exogyra matheronana (d'Orbigny)										x							
E. cf. *pyrenaica* Leymerie												x					
Gervillea solenoidea Defrance				x													
Globigerina sp		x															
Globorotalia cf. *globulosa* (Ehrenberg)		x															
Globotruncana linneana (d'Orbigny)		x															
Gryphaea proboscidea (d'Archiac)									x								
G. (*Pycnodonta*) *vesicularis* (Lamarck)	x			x	x												
Hemiaster sp	x																
Hemipneustes aff. *pyrenaicus* Hebert																	x
Inoceramus cripsii Mantell				x	x												
I. sp												x					
Iraniaster sp	x																
Janira quadricostata Sowerby				x													
Linthia sp														x			
Loftusia morgani Douvillé			x														
L. persica Brady			x														
Lopha cf. *dichotoma* Bayle	x																
Nerita aff. *pontica* d'Archiac								x									
Omphalocyclus macropora (Lamarck)			x														
Ornithaster aff. *everistei* Cotteau																x	
Praeradiolites (2 species)							x										
Radula interplicosa Stoliczka				x													
Rhynchonella plicatiloides Stoliczka				x													
R. sp						x											
Rispolia cf. *douvillei* Lambert and Thiery																	x
Terebratula biplicata Sowerby				x													
T. (large)						x											
Tholaster n. sp																	x
Turricula cf. *arrialoorensis* Stoliczka				x													
Turritella cf. *sexlineata* Roemer				x													
Verruca sp																x	
Vola sp					x												

[See references on page 63]

exponens Sowerby from somewhere between Gwadar and Jalq in the southeast. Similar beds containing *Nummulites* and *"Alveolina"* were reported near Dizak and the village of Kalpurkan by Blanford, who reported the usual series of nummulitic shales and sandstones in the Kuh-i-Bampusht, in the center of which the rocks are somewhat altered; he showed that these rocks are metamorphosed into roofing slate in the Sianeh Kuh between Isfandak and Kalagan south of Jalq. He found "Nummulitic limestone" in the Kuh-i-Birg between Khash and Galehzaboli (formerly Magas).

Griesbach (1887, p. 100) first mentioned Eocene in the vicinity of Nishapur in the north, and Vredenburg (1901) determined extensive Eocene, which he classified as "Flysch (volcanic)," Ranikot, and Khirthar, on the border of British Baluchistan. Pilgrim (1923) mapped an extension of the Indian Eocene deposits along the south coast of Iran as far as the Strait of Hormuz, and the geologists of Amiranian Oil Company have extended this area, with possible breaks, into the northwest corner of British Baluchistan and the region west of Seistan. Abundant nummulitic layers have been sampled as far north as Seistan.

Eocene deposits, which are predominantly shaly, crop out in a large area north and northwest of the Zahidan massif (Pl. 7). Throughout a considerable area west of Seistan and east of the Dasht-i-Lut a probable thickness of 6000 feet of Eocene is, according to Reeves, broken by a few anticlines having cores of Cretaceous and Eocene rocks. In this area thin-bedded limestones containing Eocene *Nummulites* are interstratified or lenticular in sandstones and gray-green shales. Reeves

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Localities of collections:

1. Santonian or Campanian, from Pusht-i-Kuh at Imam-Hassan near Kasr-i-Shirin, western Iran (Lees, 1938, p. 143).
2. Various localities in western Iran (Lees, 1938, p. 143).
3. Maestrichtian fauna in southwest Iran (Lees, 1938, p. 143).
4. Near Zirab in Talar valley (Tietze, 1881).
5. In light brown sandy marl rich in forams, in Pardshita region (Krumbeck, 1922).
6. Maestrichtian or Danian in south slope of Karaguli Dagh, 32 miles (51 km.) northeast from Gunbad-i-Qabus and 8 miles (13 km.) northwest from Gurgan River (T-20).
7. Upper Senonian, from locality 4 miles (6.5 km.) southwest from Surukhs, 200 feet stratigraphically below base of Upper Cretaceous "red beds" (S-3720).
8. Upper Senonian, a few feet stratigraphically below collection No. 7 (S-3720X).
9. Lahr-Surkhet (De Böckh, Lees, and Richardson, 1929, p. 139).
10. Madar-i-Shah, 64 miles (102 km.) northwest from Isfahan (De Böckh *et al.*, 1929, p. 139).
11. In a gorge 3 miles (5 km.) south from Surukhs (R-45).
12. Upper Senonian from bluff along Hari Rud, 5 miles (8 km.) east from Janet-abad (R-48).
13. Maestrichtian or (more probably) Danian from 8 miles (13 km.) north from Khur (R-144).
14. Maestrichtian or Danian from 15 miles (24 km.) north from Khur (R-145).
15. From Upper Sar Su village on road from Gurgan to Maraveh-tepeh, 22 miles (35 km.) southwest from Maraveh-tepeh.
16. Danian from south slope of Karaguli Dagh, 32 miles (52 km.) N. 31° E. from Gunbad-i-Qabus (T-20, H-G11-158).
17. Undefined locality, probably in eastern Gurgan province (H-14).

mapped the series over great areas between the Meshed-Zahidan highway and the Afghan frontier.

Although limestones (some of which are more than 300 feet thick) in the southeastern Eocene area may be lenticular and only of short lateral extent, as asserted by Thompson, such is not true in the northeast where, by contrast, persistent Eocene limestone of similar thickness forms the outer mountain front north of the Muzduran Pass Cretaceous section (Pl. 7). Yet, in an intermediate position, Eocene shales underlie thick sections of volcanic rocks in several interior basins between the Elburz Mountains and the Gulshan uplands and from Afghanistan west to central Iran.

Eocene is sometimes unconformable on the Cretaceous in eastern Iran. An unconformity or disconformity is exposed at the base of the Eocene in the gorges north of Muzduran Pass (Fig. 6). Likewise Eocene appears to rest unconformably upon older rocks north of the Zahidan massif near Diwan-Chah (S-3816) 29 miles (46.5 km.) north from Zahidan. Again (S-3817), in Lat. 33° 18′ N., Long. 59° 14′ E., flat-lying, gray, veined, marine miliolid-bearing limestones rest on indurated pre-Tertiary vertically standing conglomerates, sandstones, and limestones. Rivière (1934a, p. 58) found the Middle Eocene unconformable upon Upper Jurassic rocks near Aineversan in the central Elburz.

Although the Eocene thickness in the Muzduran Pass section may not be over 2000 feet, in the southeast it ranges from 5000 to possibly 7000 feet. Since Eocene rocks of eastern Iran are more closely related to the Tertiary of India than to that in other parts of the world, one can infer the correlations indicated by Table 28.

Lower Eocene.—The Ranikot (Paleocene of Davies, 1934) sea has been proven by L. M. Davies (1938, p. 202) to have extended at least from India to eastern Iran. Although the use of the term "Paleocene" may be unnecessary in eastern Iran, recent explorations in northern Afghanistan, correlated on the basis of central Asian literature, indicate widespread presence of lowermost Eocene. Rivière (1934a, p. 66-70) found Lower Eocene with rather complicated structural relations in the central Elburz system.

In southwest Iran these rocks consist of gypsums and red marls (Lees, 1938, p. 143). In a few places in eastern Iran the presence of "Paleocene" or lowermost Lower Eocene is indicated by recent collections, particularly in the southeast-central area between Zahidan and Neh. This Eocene was found (1) 40 miles (64 km.) S. 80° W. from Sefid-abeh (R-106), (2) 1 mile (2 km.) S. 20° W. from Murkh-i-Surkh (R-113), (3) 5 miles (8 km.) N. 20° W. from Jarika (R-111), and (4) along the main highway 27 miles (42 km.) north from Zahidan (R-112). Recent

FIGURE 1. LOOKING WEST FROM HURMUK
Northern Makran province, showing Eocene rocks and interbedded basalt flows.

FIGURE 2. CONTACT OF UPPER CRETACEOUS AND EOCENE SERIES
Between Surukhs and Muzduran Pass, northeast Khurasan.

FIGURE 3. GORGE THROUGH OUTCROP OF LOWER EOCENE LIMESTONE
At Padagi, 5 miles northwest of Hurmuk, Makran province.

FIGURE 1. DIKE IN "GREEN SERIES"
Near Rudahan, Tehran province.

FIGURE 2. SOUTH FACE OF MT. TOCHAL
Composed entirely of "green series", looking across valley of Shimran, north of Tehran, Tehran province.

FIGURE 3. SNOW-CAPPED ELBURZ
Composed of "green series", 1 mile north of Ferahzad, northwest of Tehran, Tehran province.

studies of the Dizak region, in southeast Iran north of the Kuh-i-Bampusht, resulted in the discovery of several lower Eocene genera.

Although the metamorphosed deposits near Zahidan have yielded no fossils, Eocene species were determined (R-104?, R-106, R-113) in up-

TABLE 28.—*Lower Tertiary rocks of eastern Iran*

American classifications	European divisions	Correlations with India	Groups reported in eastern Iran
Oligocene	Aquitanian (in part)		Asmari
	Stampian	Nari	Khamir
Upper Eocene			Upper Eocene (non-marine)
Middle Eocene	Lutetian	Khirthar	Khirthar
		Laki	Laki
Lower Eocene	Suessonian	Ranikot	Ranikot

lifted belts west of Sefid-abeh. Vredenburg (1901) found *Nummulites, Alveolina,* and sundry fossils in 1000 feet or more of gray shales with interstratified limestone bands near Kuh-i-Malik Siah at the common corner of Iran, Baluchistan, and Afghanistan. An overlying limestone several hundred feet in thickness of Ranikot or lower Khirthar age was reported.

Middle Eocene.—Pinfold (1937), who described a large number of Indian species, used the well-known term Laki for Middle Eocene above the Ranikot group, enabling correlation with the Lutetian in part. In the vicinity of Surukhs, northeast of Muzduran Pass, the reported Middle Eocene consists of 600 feet of white limestone and shale. That the Laki may be present in Iran was demonstrated by L. M. Davies (1938) through the determination, by Harrison at Shamshir-i-Quli in western Iran, of *Alveolina lepidula* Schwager, *A.* cf. *oblonga* d'Orbigny, and *Orbitolites* cf. *complanata* Lamarck. Middle Eocene has recently been determined by Schenck in a collection containing abundant *Operculina* and less numerous *Discocyclina* species from near Padagi (C-3) about 5 miles (8 km.) northwest from Hurmuk and in many other localities.

Other Middle Eocene determinations were made from: (1) A gorge 3 miles (5 km.) south from Surukhs (R-45, R-46, S-3723); (2) the mountains 2 miles (3 km.) north of Duruna (R-69); (3) beds with *Nummulites* aff. *laevigatus* Lamarck from near the Tehran-Meshed highway 41¾ miles

TABLE 29.—*Lutetian fossils from northern Iran* *

Name	1	2	3	4	5	6	7	8	9	10
Assilina sp	x									
Alveolina subpyrenaica Leymerie			x							
A. subpyrenaica var. *globosa*			x							
Biloculina sp										x
Calyptraea sp		x								
Cerithium cf. *stoddardi* Hislop								x		
Crassatellites sp		x								
Cucullaea sp		x								
Dentalium sp		x								
Dictyoconoides sp	x									
Ditremaster degrangei Cotteau									x	
Globularia cf. *brevispira* Leymerie	x									
Lithothamnium biserialis Dietrich *in* Hedin										x
L. sp										x
Lucina aff. *gigantea* Deshayes								x		
Nummulites atacicus Leymerie							x			
N. distans Deshayes					x					
N. gallensis Heim				x			x			
N. irregularis Deshayes			x							
N. (large)		x								
N. lucasana Defrance					x					
N. perforatus Denys de Montfort				x		x	x			
N. uroniensis Heim					x					
N. sp	x									
Orbitoides (*Orthophragmina*) sp										x
Ostrea sp	x	x								
Protocardia sp		x								
Septifer sp		x								
Textularia sp										x
Turritella sp		x								
"*Velates schmideliana* (Chemnitz)"				x						
Venericardia planicosta Lamarck (*sensu lato*)		x								
Ostracoda		x								
Corals	x									
Gastropoda	x									
Pelecypoda	x									

* Attention is directed to the fact that, according to some paleontologists, the following names apply to one and the same species of *Nummulites: aturicus, crassus, obtusus, perforatus,* and *uroniensis.* The earliest name is that by Montfort; hence, *Nummulites perforatus* is probably the correct name.

Localities of collections:

1. An interior valley 1 mile (2 km.) north from Kalateh, 19 miles (30 km.) N. 30° W. from Damghan (R-18).
2. "Dichileh Mountain," 20 miles (32 km.) south from Shahrud (R-25).
3. Lowermost Lutetian beds—150 feet of hard gray to black limestone in valley of Hablé Rud south of Firuz Kuh (Furon, 1938, p. 1492).
4. Near Samnan (Furon, 1938, p. 1493).
5. Near Gur Sefid (Furon, 1938, p. 1493).
6. Near Abbassabad, between Samnan and Sabzawar (Furon, 1938, p. 1493).
7. Limestone in midst of tuffs, 12 miles (20 km.) north from Turbat-i-Haidari (Furon, 1938, p. 1493).
8. 9 miles (14.5 km.) S. 45° E. from Talhap (R-98A).
9. 4 miles (6 km.) N. 85° W. from Abbasabad (R-96).
10. Hedin's loc. 176, 38 miles (61 km.) easterly from Neh and 19 miles (31 km.) southwest from Siah Kuh on the Afghan border (Dietrich, 1927).

(78 kms.) west from Abbassabad (R-93); and (4) a large and varied collection of *Nummulites, Assilinas,* and other invertebrates occurs 9 miles (15 km.) S. 45′ E. from Talhap (R-98, R-98A, R-99). Upper Lutetian was determined by Schenck from 4 miles (6 km.) N. 85° W. from Abbassabad (R-96).

Middle Eocene is also present in the southeast (Pl. 7). Thompson found (T-57, T-59) Khirthar beds with *Assilina granulosa* d'Archiac at a point about 1 mile (2 km.) N. 77° E. from Kalpurkan and indeterminate pelecypods in fine-grained sandstone (H-38, H-42) 1 to 6 miles (2 to 9 km.) from Kalpurkan on the road to Dizak. Schenck collected Middle Eocene Foraminifera at a locality 37 miles (80 km.) northwest from Zahidan in limestone about 75 feet above an ultrabasic igneous rock and somewhat below green shales and sandstones which he finds correspond

> "in appearance and position to the green beds ('couches vertes') of the Elburz Mountains and to the rocks exposed . . . west of Sefid-abeh."

(Pl. 8). Schenck also determined large Khirthar *Nummulites perforatus* (Montfort) in gray limestone (S-3811, H-36) 84 miles (134 km.) northwest from Zahidan. Khirthar was reported by Vredenburg at Saindak (British Baluchistan) 50 miles (80 km.) southeast of Zahidan, carrying *"Nummulites" granulosa* d'Archiac and Haime, *Macropsis venustula,* and *Velates "schmideliana* (Chemnitz)." In addition, Howard M. Kirk, working for Inland Exploration Company in Afghanistan, found large specimens of *Alveolina* of Middle Eocene age in a thick section one mile S. 65° E. from Kuh-i-Malik Siah. In the vicinity of the Kunji Rud and Darvazeh-i-Nadir, in the mountains southwest of Nosratabad-Sipi, Schenck measured a 4000-foot section (Table 30).

In general the higher Middle Eocene formations are less widely known in eastern Iran than are lower ones. In character the upper beds are commonly light green to gray, marine gypsiferous clay shale (R-53, S-3722), with some sandstone and conglomerates; they may attain a thickness of 2000 feet or more. Collections (S-389) were made in Lat. 30°43′ N., Long. 50°25′ E., 23 miles (37 km.) west from the Chehil-Duktaran triangulation station north of Zahidan. Hedin (1918) considered similar beds from Kirtaka and Saindak (Baluchistan) as being either Middle or Upper Eocene, above which lies 3000 feet or more of unfossiliferous greenish beds resembling the "green series" of north-central Iran. Limestones and tuffs in the vicinity of Saindak, 50 miles (80 km.) southeast of Zahidan and 18 miles (29 km.) northeast of Mirjawa, may be in part upper Middle Eocene, but they were thought by Vredenburg (1901) to be in part of Nari age.

"Ginau series" of Pilgrim.—Previous to the recent explorations some attempt had been made to subdivide the Eocene. Pilgrim (1924, p. 74)

described two geologic formations in the Kerman region of south-central Iran: the "Ginau series" and the "Zindan series." The Ginau, locally underlying Oligocene limestone, consists of 1500 feet of gray or greenish shales with thin limestone bands, having pockets and nodules of brown

TABLE 30.—*Eocene series near Nosratabad-Sipi*

	Fossils	Description	Feet
	Unconformity		
Upper Eocene (?)	No marine fossils collected	Siltstone and shale; conglomerates at base; some gray sandstone	2000+
Middle Eocene	Abundant *Nummulites "perforatus"*, large thin *Discocyclina*, *Chlamys* (S-3812)*	Steel-gray shale, weathering green	350
	Large *Nummulites*, small robust radiate *Nummulites*, *Discocyclina* (S-3813)**	Rhythmically bedded sandstone; occasional shales	500
	Nummulites cf. *atacicus*, *Discocyclina* (thin, granulate), corals (S-3814)†		
	Numerous *Nummulites* and *Assilina* (S-3815)	Gray shale, weathering green; thin sandstones and conglomerates	1000
	Abundant *Assilina* aff. *exponens* (S-3815A)††		
	Total.....	.....	3850+

* Middle Khirthar, correlates with T-59 near Dizak.
** 700 feet stratigraphically below S-3812.
† About 800 feet stratigraphically below S-3812 (Schenck considers this bed Khirthar).
†† About 75 feet stratigraphically below S-3815.

chert. Below, and part of the same series, is 600 feet of thin-bedded limestones with interbedded shales, pseudo-conglomerate, and chert, resting upon Cretaceous limestone where the contact is not faulted. This section is correlated by Schenck with at least a part of the Eocene of the Kunji Rud section near Nosratabad-Sipi and with similar rocks seen by Thompson near Dizak. A few fossils (Table 31) were found in the "Ginau series" in (1) the gorge of Tang-Shah and at (2) Khamir indicating (according to Schenck) that it is post-Ranikot.

"Zindan series" of Pilgrim.—The "Zindan series," observed by Pilgrim on both sides of the Zindan range, consists of hard unfossiliferous sandstones and gypsiferous clays which contain abundant calcite; sand-

stones predominate in the lower part and clays above. Tipper is quoted by Pilgrim (1924, p. 74) as observing this series in the Birinti gorge and also between Pozug and Ichan, and it was correlated with a series, seen by Blanford (1876, p. 452, 472-478) between Gwadar (British Baluchistan) and Jalq, containing *Assilina exponens* Sowerby, *Nummulites*

TABLE 31.—*Fossils of "Ginau series"*

Name	1	2
Alveolina sp.	.....	x
Assilina spira de Roissy	x	.....
Nummulites atacicus Leymerie	.....	x
*N. perforatus** de Montfort	x	.....
Pyrina sp.	x	.....
Salenia sp.	x	.....

* This is a Khirthar species.

sp. allied to *N. lyelli* d'Archiac and Haime, and *Nummulites* sp. allied to *N. vicaryi* d'Archiac and Haime. This "series" is placed by Schenck in post-Ranikot age.

Upper Eocene.—According to Schenck no fossils of Upper Eocene age have been reported from eastern Iran, and the occurrence of marine strata of this age is therefore problematical. The 2000 feet of siltstone and shale, having conglomerates at the base and containing some gray sandstone, lying above the determined Middle Eocene shales in the Kunji Rud to Nosratabad-Sipi section may be either Middle or Upper Eocene or Oligocene in age.

Undivided Eocene.—In addition to the definitely determined localities mentioned herein, the available records indicate Eocene in many places where the series has not been subdivided. Although these are probably Middle Eocene in general a reference to them may be helpful; the localities are therefore mentioned in Table 32.

In addition to those mentioned in Table 32 a few small unclassified Eocene inliers were found in synclinal positions in the Cretaceous area between Lutfabad and Maraveh-tepeh in the North. A few sections are reported:

1.—Section at Garm-ab, on Bujnurd-Maraveh road, 58 miles (83 km.) northwest from Bujnurd
(Thompson and Others)

Unconformity

	Feet
Light buff limestone, grading upward into coarse, white calcareous sandstone (H-31) with scaphopods, *Ostrea*, calcareous algae	500

Rests on Upper Cretaceous.

2.—Section between Robat and Bujnurd
(Thompson and Others)

Unconformity	
2. Conglomerate	1000
1. Coarse white sandstone, calcareous in spots	500
Total	1500

3.—Section near Kalat-i-Nadiri
(Reeves and Buie)

Unconformity	
Thin-bedded limestone	200

4.—Section between Muzduran Pass and Surukhs
(Schenck, Reeves, and Buie)

Unconformity	
Clay shales with Eocene oysters	1000+
Well-bedded limestone, sandstone, and shale (R-45, R-46, S-3723), *Cerithium, Nummulites, Ostrea, Turritella, Venericardia planicosta* (Lamarck) *(sensu lato)*	575
	1575+

In the central Elburz System, Eocene has been identified with certainty (Rivière, 1934a, p. 56) south of the Nour valley in (1) Localities between 10 and 25 miles (15 and 40 km.) southeast from Mt. Demavend,

TABLE 32.—*Localities of other Eocene collections*

No.	Locality
1	10 miles (16 km.) N. 10 W. from Damghan (R-47A).
2	8½ miles (13.5 km.) east from Zaidar on the same road (R-95).
3	6 miles (9.5 km.) N. 80 W. from Maluman (R-121, R-127).
4	6 miles (9 km.) east from Chah-i-Chirin (R-129).
5	4 miles (6 km.) east from Chah-i-Chirin (R-131).
6	Vertical beds carrying *Discocyclina* and *Nummulites* 4½ miles (7 km.) south from Rum and 6 miles (9 km.) north from Sehdeh on Zahidan-Birjand road (S-387).
7	Veined limestone, with calcareous algae, corals, and miliolids, 15½ miles (25 km.) southwest from Sefid-abeh.
8	10 miles (16 km.) west from Anjareh, west of Sefid-abeh (R-108).
9	5 miles (8 km.) N. 45 E. from Anjareh (R-109).
10	1½ miles (2.5 km.) east from Hurmuk (C-7).
11	45 miles (76 km.) northwest from Zahidan; in black limestone with *Nummulites* (C-8).
12	2 miles (3 km.) N. 77 E. from village of Kalpurkan. (T-56 to T-60).
13	7 miles (11 km.) N. 45 W. from Sefid-abeh (R-101).
14	"Miliolid limestone" 5 miles (8 km.) south from Hasanabad and 14 miles (22 km.) west from Sefid-abeh (T-31).

(2) 17 miles (28 km.) southwest from Mt. Demavend, and (3) in a belt extending west-northwest from the summit of Mt. Demavend. Nummulitic limestones overlain by marl-sandstones were found (4) near Anderieh in Nim Rud valley at a point 14 miles (23 km.) west-northwest

from Firuzkuh (Stahl, 1897). Again, (5) "Nummulitic limestones" overlie Upper Jurassic near Kelerend in the Heras valley northeast of Mt. Demavend (Stahl, 1897), and (6) black limestones with small *Nummulites* lie beneath the "green series" in the Zarin Kuh, north of Jahbun and 3 to

TABLE 33.—*Eocene section in eastern Makran*

No.	Description	Feet
6	Gray calcareous shale	500
5	Fine-grained calcareous gray sandstone—the top thin-bedded, the lower part medium-bedded with some cross-bedding	600
4	Calcareous gray shales with thin calcareous sandstones and sandy limestone beds	500
3	Thin-bedded calcareous sandstone with some gray shale	250
2	Calcareous gray shale with thin interbedded sandstones	1000
1	Fine-grained, thin-bedded calcareous gray sandstones and occasional conglomerate beds	1000
	Total	3850

12 miles (5 to 20 km.) east from Demavend village (Rivière, 1934a, p. 57); (7) black limestone, rarely containing small *Nummulites* (Rivière, 1934a, p. 57), was found near Ab-bala, north of Rudahan. (8) In the Sefid-ab valley west of Mt. Demavend, Jurassic limestones are overlain by whitish limestones containing *Nummulites perforatus* de Montfort (Rivière, 1934a, p. 57). Lastly, (9) in the Nim Rud valley, near the pass connecting it with the Heras, the same limestone contains similar *Nummulites* (Rivière, 1934a, p. 57).

Thompson collected an abundance of *Alveolina* and *Nummulites perforatus* near Khash in the southeast. The Badamo Mountains, which bound the Khash-Dizak valley on the northeast, expose about 2000 feet of thin-bedded limestones, fine-grained calcareous sandstones, and shales. The section contains several nummulitic horizons and dense limestones with *Alveolina, Lithothamnium,* Bryozoa, and miliolids. An interbedded sandstone formation is exposed in the lower part of the Eocene series of 5000 feet or more on the west side of the Karwandar valley between Khash and Iranshahr (formerly Fahraj). Dark and maroon shales also are found, containing *Nummulites* and some *Venericardia, Alveolina,* miliolids, Bryozoa, and complex corals. Hotchkiss measured a thick Eocene section (Table 33) near the Mashkel River north of the Kuh-i-Bampusht.

Lenses of massive limestone of detrital origin were reported by Blanford at many localities in the southeast (Pl. 10, fig. 2); recent work has resulted in similar discoveries north and southwest of the Zahidan massif.

Some of these lenses are 200 to 350 feet thick, a mile across, and several miles long. Similar limestones may be present in the Zindan Range near Kerman.

Eocene and so-called Eocene volcanic rocks.—An important eruptive period may have commenced in Lower or Middle Eocene time and continued through Oligocene and perhaps into Miocene time. Basic volcanic, pyroclastic, and intrusive rocks associated with Lower Tertiary series are extensive and represent widespread volcanic activity. These rocks are in places thousands of feet thick; and, although they may casually appear to be mainly tuffs, flows are also important. Since they are represented as "volcanics," or as "Eocene and volcanics," on all field maps submitted, and since studies have not been made with the particular object in view of separating dikes and necks from tuffs, lavas, and sills, it is not possible to differentiate them in the present mapping. The geologists employed on the recent studies had duties that prevented them from giving time to the separation of intrusive, extrusive, and pyroclastic rocks of Eocene age from similar formations of other ages. In the south, in particular, widespread volcanic activity undoubtedly existed in Cretaceous time and, in the north, as late as Pliocene. Hedin (1918; 1927) gave much attention to the details of volcanic rocks. The confusion which persists as to ages of any "volcanic series" mapped by a field geologist and as to differences in the nomenclature used by several individuals renders it impossible at this time to say that the collective term used on the accompanying map represents a single cartographic unit. In fact, probabilities are quite to the contrary. Parts of the "volcanic series" as mapped may be Cretaceous, but Mounts Demavend and Kuh-i-Taftan evince, by contrast, volcanic activity which is hardly extinct.

The point emphasized here is that the Eocene "volcanic series" in itself does not form a unit but that marine beds may constitute the larger part of mapped "volcanic" areas. The series undoubtedly will be subdivided in time into formations and members, or at least into areas of thin lava flows as opposed to thick ones, and again a distinction will be made between flow and tuffaceous areas. Since the "volcanic" series is so widespread it was obviously formed by eruptions at widely separated centers, yet the intervening areas are not destitute of volcanic rocks. The diversity and interrupted but general presence of this series, both horizontally and vertically, is very apparent.

Inasmuch as eruptions were widely separated geographically it is not at all probable that a central or northern "volcanic series" can be correlated with Pilgrim's (1924, p. 72) Lower Eocene "Panj," said to consist of 2000 to 3000 feet of diorite. Nor need it be assumed that Stahl's acidic volcanic rocks, mapped north of Shahr-i-Babak and north of Kuhbanan,

are of the age of the north-central "volcanic series." Tipper's (1921, p. 68) dark lavas and tuffs on the north slopes of the Gudar-i-Gishu may likewise be excluded.

Oligocene series.—Little is definitely known of Oligocene strata in eastern Iran, although their distribution may be extensive. However, the deposition of Asmari limestone in west and southwest Iran took place mainly in Oligocene time (Lees, 1938, p. 144). This formation is named from a mountain a few miles south of Masjid-i-Suleiman. Where present the rock is a fine-grained, foraminiferal limestone, sometimes 900 feet thick, having some interstratified shale and carrying anhydrite beds near its base.

In the southwest the "Khamir series," a porous reef development about 1200 feet in thickness of nummulitic limestone and dolomite (Lees, 1933, p. 144), first reported by Pilgrim (1924, p. 28-81), rests unconformably upon Eocene shales or "Hormuz conglomerate." At the type locality on Clarence Strait the lower Khamir consists of 400 feet of cream-colored limestones interbedded with sandy and occasionally shelly layers, above which is reported (Pilgrim, 1924) 300 feet of thick-bedded massive sandstone interstratified with shelly limestones—one band crowded with *Nummulites intermedius-fichteli* and another containing gypsum and barite. At the east end of the Ginau Range, 18 miles from the Persian Gulf, this series rests on Ginau limestone of Eocene age.

At Tang-Khah, 14 miles (23 km.) north from Bandar'Abbas, and elsewhere, Pilgrim reported a still greater thickness of massive limestone having a reddish tinge, resting on Eocene shales and unconformable beneath the Fars (Miocene) gypsums and limestones. In the same region Pilgrim (1924, p. 78) found purple conglomeratic limestone at the base of the Khamir series. He remarked that the fauna can confidently be placed in the "Stampian" and he correlated the Khamir with the Lower Nari beds of India which range in age from Stampian to Aquitanian. Asmari limestone carrying *Lepidocyclina* has been recognized in central Iran as far northeast as (1) An outcrop 3 miles (5 km.) southwest from Qum (S-372) and (2) at Hassan Rud (S-3735) 15 miles (24 km.) southeast from Kashan. Furon and Marie (1939) have recorded an identification of fossils collected by Furon from shales considered as of Aquitanian age in the vicinity of Qum. The species are enumerated as follows:

Amphistegina lessonii d'Orbigny
Cibicides lobatula (Walker and Jacob)
Clavulina cf. *szaboï* Hantken
Cornuspira sp.
Cristellaria sp.
Discorbis patellinoides Brady
D. vesicularis Lamarck
Gaudryina cf. *trinitatensis* Nuttall
Globigerina sp.
Guttulina austriaca d'Orbigny
Heterostegina costata d'Orbigny
H. sp.
Miogypsina complanata Schlumberger
M. irregularis Michelotti
Pulvinula sp.
Rotalia viennoti Grèig.
Technitella sp.
Textularia sp.

The so-called "green series" (pl. 8), which resembles the "Flysch" beds of Vredenburg (1901) and is composed largely of tuffs, makes up broad frontal portions of the Elburz Mountains and extends far southward; it was considered by Rivière (1934a, p. 59-63) as Oligocene. Since Miocene strata rest unconformably on these rocks, we have no positive evidence that the upper part of the "green series" may not be Oligocene; yet the lower portion is evidently Eocene as has already been pointed out. Although the evidence for this conclusion has been gradually increasing in recent years the critical argument was brought out in recent work. An important factor in the argument is work by Schenck and Rieben who, in a conformable section in the valley of Nim Rud west of Firuz Kuh, collected Middle Eocene Foraminifera just below the "green beds" of Stahl and Rivière. The role which this series plays in Elburz structure is of fundamental importance, since such rocks infolded far into the central mountain area are of great thickness. An elaboration of the case in favor of the Eocene age of the "green beds" was presented by Schenck (1939) in a recent paper, which also included a petrographic report by A. C. Waters on a sample of the so-called "palagonitic tuff."

In discussing the stratigraphic position of these rocks, Rivière (1934a, p. 61) states that, north of Ab-bala village in the valley above Rudahan, Eocene nummulitic limestones are overlain by 430 feet of bedded, light-colored, and sometimes brecciated limestones, on top of which lie puddingstones and reddish sandstones containing fragments of various older rocks and having intercalated black limestones containing *Nummulites;* above all this is the "green series." Stahl (Rivière, 1934a) called attention to the occasional presence of gypsum in massive form in the "green series." A notable mass is visible from Kandavan Pass in the Elburz between Karaj and Chalus, and Rivière reports similar occurrences near Oudjékala, Jalou, Lazour, and in the Jajrud valley.

In general, the lavas, flows, and sills of this series have a basic composition, and the pyroclastic beds were considered by Stahl (Rivière, 1934a, p. 60) as palagonites. The "green series," however, consists of numerous facies which grade from green marly limestones to black shales, and more commonly agglomerates and tuffs of varied hue but of a predominantly greenish tinge. No marine fossils have been reported in strata positively identified as the "green series."

MIOCENE SERIES

Principal features.—Strata of Miocene age are extensive in eastern Iran and form (1) A major part of the surface of certain uplands north of the Dasht-i-Kavir, (2) scattered hills between Gunabad and Turbat-i-Haidari in eastern Iran, and (3) apparently some of the border belts against the

FIGURE 1. WEST DIPS IN SALT
At east end of salt hill.

FIGURE 2. GENERAL VIEW OF EAST END OF SALT DOME
Showing salt glacier on the right.

FIGURE 3. QUARRYING ROCK SALT
Kuh-i-Namak.

KUH-I-NAMAK SALT DOME INTRUDED INTO MIDDLE MIOCENE, NEAR QUM

FIGURE 1. BLACK SLATE OF LIASSIC AGE
Between Meshed and Nishapur.

FIGURE 2. OUTCROP OF NUMMULITIC LIMESTONE
14 miles east from Nosratabad-Sipi, northern Makran province.

FIGURE 3. OVERTURNED FOLD IN NEOGENE CONGLOMERATE
Looking northwest from point 1 mile south from Leshkerek, Tehran province.

LIASSIC SLATE, EOCENE LIMESTONE, AND NEOGENE FOLDING

Elburz Mountains. Griesbach (1887, p. 100) correlated the Miocene of southwest Afghanistan with gypsiferous Fars described by Loftus (1855, p. 254-270). It is probable that certain clays surrounding mountain belts between Meshed and the Afghan border, as well as numerous intra-desert

TABLE 34.—*Neogene series of eastern Iran*

American classification	European divisions	Groups reported in eastern Iran		Subdivisions in southwest Iran	Feet
Pliocene	Pliocene				
Unconformity				Bakhtiari	15,000
Miocene		Pontian			
	Upper Miocene	Vindobonian	Sarmatian	Upper Fars	5000
	Middle Miocene		Tortonian	Middle Fars	1000–10,000
	Lower Miocene	Burdigalian		Lower Fars	800–6000
Oligocene	Oligocene	Aquitanian		Asmari	0–300
		Stampian		Khamir	

swells here undifferentiated from Eocene or from Pliocene (Pl. 1), may be Miocene.

In general, the Miocene appears to be unconformable on the Eocene and Oligocene. Reeves reports an unconformity at the base of the Miocene in the Samnan area, and Pilgrim (1924, p. 79) inferred similarly as to southwest Iran. Some of Iran's typical Miocene invertebrate fossils were figured by Douglas (1927-1928) and by Cox (1936). The fauna collected by Tietze, in the Siah Kuh district of central Iran, was considered Aquitanian and Burdigalian by Fuchs (1879). The subdivisions of this and the coterminous series are given in Table 34.

Southwest Iran.—In the southwest, the Miocene has at its base the Asmari limestone (mainly Oligocene), above which lie the Lower, Middle, and Upper Fars, the inclusive name for which was first proposed by Pilgrim (1908, p. 26). This group, as described by Lees (1938, p. 144) for that part of Iran, has the characteristics summarized in Table 35.

Central Iran.—Lower Miocene limestones are identifiable 17 miles (24 km.) by road southwest from Kashan and also in the Siah Kuh region of

TABLE 35.—*Miocene series in Southwest Iran*

Series	Groups	Feet	Characteristics
Miocene	Upper Fars	3000	Reddish, brownish, or greenish marls with thin bands of brownish sandstone (Pilgrim's *Pecten vasseli* beds).
	Middle Fars	0–2500	Pale-greenish or gray marls and marly limestones with abundant molluscan fauna, (Pilgrim's *Ostrea virleti* beds), in which *O. gingensis* are found. Masses of reef limestones, composed of calcareous algae and Bryozoa with some foraminiferal and coralline layers. Some interbedded gypsum. Transition from oölitic limestones below.
	Lower Fars	0–11,000	Geologists of Anglo-Iranian Oil Company have subdivided the Lower Fars into three divisions: III. Anhydrite and gray marls with some shelly limestones. II. Red and gray marls, anhydrite, and locally salt (500–700 ft.). I. Gray marls, with some thin shales and local limestones in the lower part. The variation in thickness is great.
Oligocene	Asmari Limestone		

TABLE 36.—*Miocene series in north-central Iran*

No.	Characteristics	Feet
3	Red sandstones, mottled clays, blue marls, and gray-bedded sandstones, frequently impregnated with salt and gypsum. The base may be Burdigalian and the greater part Vindobonian. The upper part, supposed to be of Tortonian age, consists of sandstones, sandy marls, and gravels, and may be equivalent to the Upper Fars and Bakhtiari of Southwest Iran.	5000*
2	A sandy "marine" division, with some limestones and Stahl's (1911, p. 18–20) "Miocene calcareous tuffs."	3100**
1	"Basal red group" of the English geologists, consisting of conglomerates, marls, and gravel; frequently saliferous and gypsiferous.	800†
	Total	8900

* Near Samnan
** Near Qum
† Near Hamadan

} The composite thickness is not definitely proven in any one locality, but may exist.

the Dasht-i-Kavir. Kuh-i-Namak, northwest from Qum (Pl. 9), is a salt dome in the Miocene in which the Miocene age of the intruded or infolded salt is not definitely proven. Table 36 gives an average character of the Miocene beds in north-central Iran.

Fuchs (1879) gives a list of the fossils found by Tietze in the "Miocene limestones" of the Siah Kuh. No exhaustive effort was made to modernize the names of the fossil forms in this list.

Miocene fossils from the Siah Kuh

Arca turonica Dujardin
Cardium burdigalinum Lamarck
C. sp.
Chenopus sp.
Conus sp.
Cypraea sp.
Fusus sp.
Lucina sp.
Lutraria sp.
Murex partschi Hoern
Natica sp.
Ostrea callifera Lamarck
O. petrosa Fuchs
O. pseudodigitalina Fuchs
O. rholfsii Fuchs
O. virleti Desh.
Pecten angustus Fuchs
"*P. beudanti* Basterot" Hoernes
P. communis Fuchs
P. cf. *deletus* Michelotti
P. difficilis Fuchs
P. malvinae Dubois
P. persicus Fuchs
P. placenta Fuchs
P. rotundatus Lamarck
P. siocutensis Fuchs
P. (*Janira*) *tietzii* Fuchs
Rostellaria aff. *dentata* Grateloup
"*Scalaria*" *intermedia* Fuchs
Telescopium charpentieri Basterot
Turritella turris Basterot
T. sp.
Venus islandicoides (Lamarck)
V. lugensis Fuchs
V. sp.
Xenophora sp.

South side of Elburz Mountains.—In the vicinity of the Elburz Mountains the Fars contains large admixtures of fanglomerates, but farther south bordering the Dasht-i-Kavir great thicknesses of Miocene of the usual shaly and sandy character are present. Throughout a number of more or less local desert areas of eastern Iran and especially on the south side of Elburz this series is extensive. In the Maluman area in the northern Kavir Reeves reports 7000 to 8000 feet of nonmarine gypsiferous clays and gypsums, the upper half of which is considered Middle Fars and the base Lower Fars. He also describes a thinning of the marine phase from 2000 feet at Chah-i-Shirin to 600 feet in a distance of only 8 miles southeastward. He states that interbedded volcanic flows lens out in the same direction; this change likewise is merely local, for other centers of eruption existed.

In the Samnan region, Reeves reports 10,000 feet or more of Middle Fars resting unconformably upon Lower Fars; the section contains about 500 feet of marine limestone. In the Khur area Reeves found a (probably Miocene) nonmarine series composed as outlined in Table 37.

North side of Elburz Mountains.—Although the Fars group may not be recognizable as such north of the Elburz, yet a great thickness of Mio-

cene is known in Mazandaran. According to Golubiatnikoff (1917) great thicknesses of Sarmatian clays, sands, sandstones, and marls containing abundant fossils have been identified in the eastern part of the Province. Table 38 enumerates the species recognized by him.

TABLE 37.—*Miocene sequence near Khur*

No.	Characteristics	Feet
4	Volcanic tuffs and flows	2000
3	Buff gypsiferous clays	1000
2	Red gypsiferous clays and red cross-bedded sandstones	2000
1	Limestone conglomerate, calcareous sandstone, and red clay	500
	Total	5000

Certain Miocene horizons of this region are likewise widespread in the southern part of Soviet Russia. The *Spaniodontella* beds of Mazandaran, reported to overlie the particular Lower Miocene beds described, may be comparable with certain upper Middle Miocene beds in the Caucasus (Goubkin, 1934, p. 617). A Pontian fauna, reported by Golubiatnikoff (1917) in the clays and sands of the Tajan Rud, is here mentioned:

Pontian fossils of Tajan Rud (river)[8]

Mactra cf. *ososkovi* Andrusov
M. grassicolis Andrusov
M. venjukow Andrusov
Melania gracilicosta
Melaniopsis bergeronis Sabba Stefanescu
Neritina scripta Sabba Stefanescu

Northeast Khurasan.—Miocene areas adjoin the Turkoman frontier in northeast Khurasan, notably in the Robat-Bujnurd section where possibly 2500 feet of conglomerates and light-gray gypsiferous clay-shale was observed. Strata of probable Fars age are found between Nishapur and Gunabad and may extend east as far as Herat in Afghanistan. Table 39 is a list of recent collections which have been reported as Miocene.

Southeast Iran.—Although Miocene rocks have not been recognized positively in southeastern Iran, Thompson reports a series of highly gypsiferous varicolored clays and silts which he considers Upper Fars, underlying, with strong angular unconformity, the Kunji conglomerate (described and named by Schenck) of probable Pliocene age somewhere between Nosratabad-Sipi and Bam. Blanford (1872, p. 43) described

[8] Since the unpublished manuscript is in Russian, translated in Iran, the names could not be modernized for present publication.

Tertiary rocks 2000 to 3000 feet thick which he named "Makran series," overlying nummulitic beds and extending 35 miles (56 km.) back from the Makran coast. He believed the Makran series might be the marine equivalent of the "Gypsiferous series" farther north.

TABLE 38.—*Middle Miocene fossils of Sari region*

Name	1	2	3	4	5	6	7	8	9	10
Buccinum duplicatum Sowerby	...	x	...	...	...	x	...	...	...	...
B. sp.	x	...	...	...	...	...	...	...	...	...
Cardium n. sp	x	...	x	...	x	...	x	...	x	...
C. fittoni d'Orbigny	x	...	...	...	x	...	...	...	...	...
C. sp.	...	...	...	...	...	...	...	...	x	...
Donax sp.	x	...	...	...	...	x	...	...	x	...
Mactra podolica var. *fabreana*	x	x	...	...	...	...	x	x	...	...
M. sp.	...	...	...	x	...	...	...	...	x	...
Solen subfragilis "Eichwald" Hoernes	...	...	...	...	x	...	...	...	...	...
S. sp.	...	x	...	...	...	...	...	...	...	...
Spaniodontella nutides Reuss	...	...	...	...	...	...	...	...	...	x
S. pulchella (Baily)	...	...	...	...	...	...	...	...	...	x
S. sp.	...	...	x	...	...	...	...	...	x	...
Tapes gregarius Partsh *in* Hoernes	x	x	...	x	...	...	...	...	...	...
Trochus sp.	...	x	...	x	...	x	...	...	...	...
Turbo sp.	...	x	...	...	...	x	...	...	...	...

Localities of the collection:

1. On road to "Tarji-kala," near Tajan Rud.
2. "Bala-kala," on Tajan Rud road, a little below mouth of Zelim Rud.
3. Various points on Tajan Rud above the mouth of Zelim Rud.
4. Village of "Sarket," farther south on Tajan Rud.
5. "Tokum," still farther south on Tajan Rud.
6. Sundry points on Tajan Rud above Zelim Rud.
7. Near village of "Germeru," 2 miles above mouth of Zelim Rud.
8. Village of "Oydash," 2 miles above Germeru.
9. On the Zelim Rud, between "Oydash" and "Azam."
10. Near village of "Azam" on Zelim Rud.

The "Makran series" has since been mentioned by Vredenburg (1901, p. 189). It was considered identical in part with the Fars of southwest Iran and the Upper Hinglaj of India, yet Blanford (1873, p. 501) postulated a Pliocene age. These beds are soft, greenish, fossiliferous, calcareous sandstones having nodular bands and interbedded gray sandstones which carry secondary gypsum in cracks. Collections were studied by Duncan and Sladen (1886). Table 40 enumerates fossils found by Tipper (1921, p. 66) and identified by Vredenburg as of Upper Hinglaj age as well as the genera enumerated by Blanford from the "Makran series". It would appear that Blanford's and Vredenburg's deposits, included under the group name, may be of different ages and that Blanford's Makran series may be Pliocene.

TABLE 39.—*Some Miocene localities in north-central Iran*

No.	Locality	Series reported
1	40 miles (64 km.) N. 60° E. from Samnan (R-84)	Middle Fars
2	3 miles (5 km.) N. 76° E. from Russian camp near Samnan (R-87, R-88)	Middle Fars
3	Village of Balo 10 miles (16 km.) north from Samnan (R-89, R-90)	Miocene
4	On Tehran highway, 19 miles (30 km.) northeast from Samnan and ½ mile (1 km.) northeast of Attareh (R-91, R-92)	Middle Fars
5	16 miles (26 km.) N. 70° E. from Samnan (R-85)	Upper Fars
6	6 miles (9.5 km.) N. 20° E. from Maluman (R-120)	.....
7	20 miles (32 km.) S. 70° W. from Maluman (R-128)	Middle Fars
8	4 miles (6.5 km.) east from Chah-i-Shirin (R-130)	Fars
9	6 miles (9.5 km.) S. 60° E. from Russian camp at Samnan (R-132)	Fars
10	12 miles (19 km.) southeast from Qum (R-134)	Miocene
11	27 miles (43.5 km.) southeast from Kashan (R-137)	Fars

TABLE 40.—*Fossils of the Makran series*

Name	1	2	3	4	5	6
Arca (several species)						x
Balanus sp.						x
Cardium sp.						x
Cerithium sp.						x
Conus (*Dunaroconus*) sp. allied to *C. cinereus* Bruguière			x			
C. (*Lithoconus*) *loroisii* Kiener (lower and upper Hinglaj)			x			
"Dolium" sp.			x			
Lucina sp.						x
Murex sp.			x			
Natica sp.				x		
Operculina sp.						x
Ostrea gryphoides Schlotheim (upper Hinglaj)		x				
O. sp.						x
Pecten nov. sp. allied to *P. vasseli* Fuchs	x					
P. sp.						x
Pulvinulina sp.						x
Triton sp.			x			
Turritella bandongensis K. Martin			x			
T. javana K. Martin, probably identical with *T. assimilis* Sowerby				x	x	
T. sp.						x

Localities of the collections:

1. Chahbar
2. "Tiz"
3. "Nur-Mohammadi"
4. "Chah-Bashua"
5. Pozug

} recorded by Tipper (1921, p. 66).

6. Forms mentioned by Blanford (1872, p. 43-44).

PLIOCENE SERIES

Classification of deposits.—Griesbach (1887, p. 100) described "upper" Tertiary deposits overlying marine Miocene beds in the Herat valley and eastern Khurasan as comprising:

Pliocene and Recent formations of northeast frontier

4. Blown sands and recent alluvium.
3. Loess deposits and old fans.
2. Fresh-water deposits with plants and land shells.
1. Estuarine deposits.

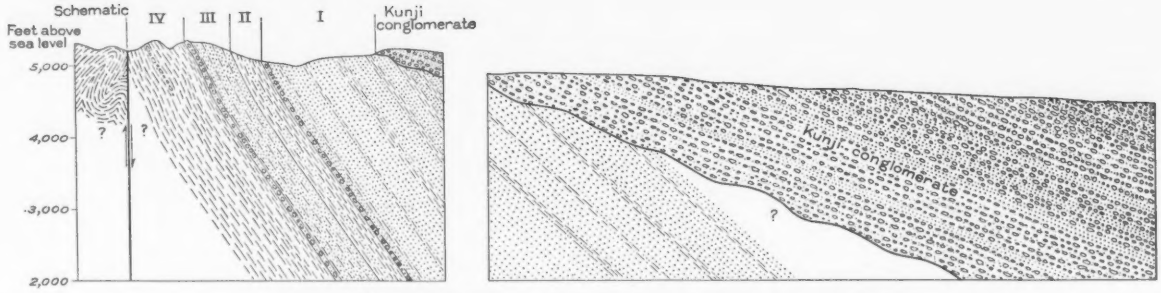
The supposed Pliocene deposits of northeast Iran are, however, limited here to (1) Gravel deposits of continental origin, (2) loess, and (3) fossiliferous beds which are exposed in northeast Gurgan.

Siwalik and Bakhtiari deposits.—The greatest deposit known in Iran, except the early Tertiary "green series", is probably the immense thicknesses of gravels, conglomerates, sandstones, and shales of continental origin (pl. 11) which overlie the Eocene and Miocene series in many parts of eastern Iran and appear in places to grade upward into Pleistocene and Recent gravels. Schenck has applied the name "Kunji conglomerate" locally to 3000 feet of cross-bedded gravels, measured southwest of Nosratabad-Sipi, or 67 miles (108 km.) west from Zahidan, where they rest unconformably upon Eocene (Fig. 8). Thompson found areas of similar beds between Nosratabad-Sipi and Bam.

Throughout Iran the gravel beds of this age are folded at high angles. It seems probable that the Bakhtiari series of southwest Iran (Tipper, 1921, p. 67) and the Siwalik of India, both of which may attain thicknesses of 15,000 feet, correspond approximately in age. They were found by the Indian Geological Survey to represent "the last effects of the earth-movements that raised the numerous mountain ranges." Vredenburg (1909, p. 217, 220) correlated the Siwalik beds with the "Gobi formation" of central Asia and recognized them as mainly of Pliocene age.

Loess.—A deposit which may be in part of Pliocene age is developed in Gurgan and northern Khurasan. Loess is widespread throughout central Asia but is supposed to be predominantly Pleistocene and is therefore described under the Quaternary system.

Fossiliferous beds.—Pliocene clays, shales, sandstones, and limestones outcrop in northern Gurgan province, where Aktchagil beds (Upper Pliocene) of Baku (U. S. S. R.) have been determined by Schenck on paleontologic evidence as far east as a locality 16 miles (26 km.) N. 15° E. from Gunbad-i-Qabus (S-377). The exposed thickness is over 300 feet, and greater thicknesses may underlie the Gurgan plains, through which



AGE	UNIT	FEET	LITHOLOGY	COL.	FOSSILS
PLIOCENE?	Kunji conglomerate	3000+	Coarse, crossbedded conglomerate Boulders up to 8", mainly igneous. Gray sandstone beds. Occasional red and green shales		
			UNCONFORMITY		
EOCENE	I	2000+	Maroon siltstone and silty shale, conglomerate at base, some gray sandstone.		
	II	350	Steel gray shale weathering green	3812	*Nummulities*
	III	500	Rhythmically bedded ss., occasional shales	3813 3814	*Discocyclina, Nummulities*
	IV	1 000+	Gray shale, weathering green, thin sandstones and conglomerates	3815 3815A	*Large Nummulites* *Nummulites*

FIGURE 8.—*Eocene-Pliocene contact*

Near Nosratabad-Sipi, northern Makran; by Amiranian Oil Company. Geology by H. G. Schenck, Henry Hotchkiss, and Khadji Afshar.

occasional patches of these beds are found. Table 41 gives an Upper Pliocene section reported by Thompson in northeast Gurgan.

Blanford (1873, p. 501) believed that part at least of the "Makran formation" of the Southeast is not older than Pliocene.

TABLE 41.—*Pliocene section in northeast Gurgan*

No.	Description	Fossils	Feet
3	Reddish gypsiferous marly clays	*Cerastoderma "umbonata"* (Wood) Ostracodes *Potamides caspius* Andrusov	60
2	Limestone conglomerate; marl-coquina beds	Cardiaceans Ostracodes *Potamides caspius* Andrusov	50–100
1	Green gypsiferous shale	Cardiaceans *Potamides caspius* Andrusov	200
	Total		310–360

QUATERNARY SYSTEM

LOESS, GRAVEL, AND ALLUVIUM

Loess.—An important Quaternary deposit is loess, the deposition of which appears to have commenced in Pliocene time in many Asiatic localities and continued throughout Pleistocene to the present time. Loess is better developed in northern Afghanistan than in Iran, although it is present in Gurgan and northwest Khurasan. Loess in Turkestan has been described by Davis (1905, p. 58-63). Although always of aeolian origin, the deposit is widely distributed both stratified and unstratified, depending on whether or not it settled into water.

The thickness of the loess is estimated by Thompson as only 300 to 500 feet in the Gurgan area. Its altitudes vary greatly, for he reports its presence on a mountain top 4000 feet above sea level, 10 miles (16 km.) southeast of Maraveh-tepeh; he believes the position is due to recent upfaulting and folding, for it evinces vertical displacements of over 3000 feet and dips of 15 to 20 degrees. Figure 1 of Plate 4 represents a recent fault observed by the writer; this fault cuts loess along a plane where the associated underlying brackish-water Pliocene beds are vertical.

In northeast Gurgan the loess sometimes forms escarpments which are, according to Thompson, due to post-Pliocene faulting—a phase of the step-fault system of the southern Caspian basin. Thompson (1938) furnishes evidence in the form of prehistoric irrigation ditches, on a ter-

race 180 feet above the existing stream courses, which combine with visible breaks in the strata to prove recent faulting.

Gravel deposits.—Another important surface formation, common in all interior valleys in plateau Iran, consists of immense deposits of outwash gravels (Blanford, 1873; Clapp, 1930, p. 74) which surround the outlets of most of the lateral valleys and largely fill the main valleys (Pl. 12). Deposition of these gravels, as of the loess, may have commenced in Pliocene time. The fans, enormous talus slopes, and thick river gravels are conspicuous in all main valleys on the high plateaus of Iran. These deposits are seldom if ever flat, although the extent of an approximately plane surface may make them appear so from certain observational positions. The slopes, consisting of many alluvial types which range from great boulders near the mountains to fine gravel and even sand and silt in the centers of wider valleys, are many miles in length with an inclination of 1 to 3 degrees, so that the difference in elevation between the top and bottom of a slope may be as much as 1000 to 2500 feet.

Lake deposits.—A third class of Pleistocene and Recent deposit is found only in a few interior basins and is generally due to continuation of conditions which originated in Pliocene time. The deposits consist largely of alternations of beds ranging from white or pinkish clays to reddish sands and silts. Huntington (1905, p. 223-228) described such beds in Seistan, where they form terraces some distances above the level of Helmund River, Hamun-i-Seistan, and Gaud-i-Zirrah (Afghanistan). The bluffs were attributed to uplifting contemporaneous with Quaternary volcanic eruptions (Huntington, 1907, p. 364-365). A series of climatic oscillations were postulated which extended through late Tertiary and all of Quaternary time. He (Huntington, 1907, p. 364-365) attempted to correlate the terraces with those found elsewhere in Iran and with the succession of glacial changes in central Asia.

Considerably farther southward Thompson mentions a series of well-stratified sands and gravels having vertical cliffs, sometimes as much as 100 feet high, on the Bampur plain and in the Karwandar valley north of Iranshahr. Such sediments appear to have been deposited in lake basins of the sort described by Huntington and dissected in subsequent climatic cycles. Vredenburg (1909, p. 220) described broad deposits of flat-lying beds, similar to Siwalik deposits but actually composed of material reworked from Pliocene gravels in the highlands bordering Gaud-i-Zirrah and other depressions. The materials of the Gurgan plains in the north, which rise slightly eastward, were deposited in Caspian waters at a stage higher than the present one.

FIGURE 1. ROAD FROM TEHRAN TO SHIMRAN
Cutting through moderately dissected Pliocene or early Pleistocene outwash gravels, with Elburz Mountains in distance.

FIGURE 2. 'KUNJI RUD GRAVELS OF PLIOCENE AGE
Resting unconformably on Eocene shales southwest of Nosratabad-Sipi, northern Makran.

FIGURE 3. GRAVELS OF KUNJI RUD OF PROBABLY SIWALIK AGE
Near Hurmuk, northeast Makran province.

PLIOCENE GRAVELS

FIGURE 1. WINDING ROAD
Across high outwash gravel deposits, west of Jajrud (river), between Tehran and Leshkerek on road to Shamshak.

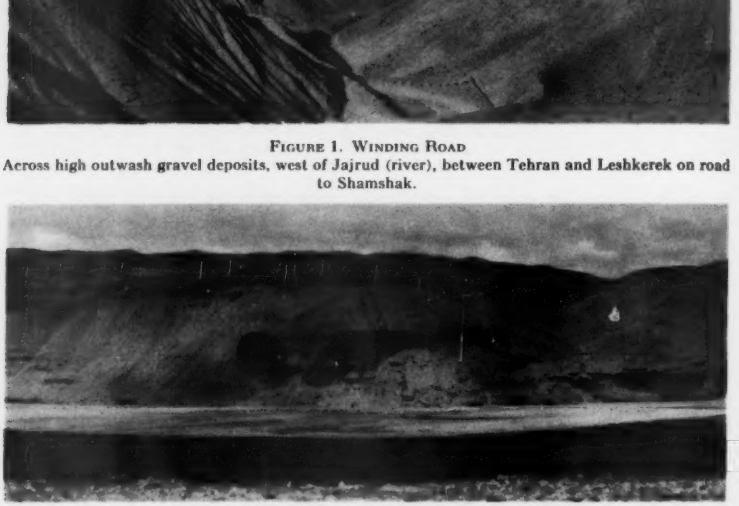


FIGURE 2. BLUFFS OF JAJRUD GRAVELS (POSSIBLY PLIOCENE)
Outcropping beneath Quaternary outwash gravels on Jajrud (river), Tehran province.

FIGURE 3. BASIC DIKES
In massive granitic mass occupying anticlinal core, 13 miles southwest from Nosratabad-Sipi, northern Makran province.

QUATERNARY GRAVELS AND IGNEOUS ROCKS

HUMAN GEOLOGY

In travelling through eastern Iran, as in many countries of western Asia, one notices surface manifestations of a geologic nature which are nevertheless attributable to the work of man (Pl. 13). Among these are thousands of mounds representing ruined cities and villages, dotted over the high plateaus as well as lowland plains, the remains of ancient irrigation ditches, and ruined walls. The several types are evident on the Gurgan plains, and the ruins of cities are abundant in the broad valleys near Meshed and in Seistan. An additional type of human geology is a surface and subsurface phenomenon (Pl. 13), seen in few other countries, in the form of small mounds surrounding vertical shafts which mark the courses of kanats, or underground water channels constructed during the past several thousand years and notably in the past few hundred years, to bring water down the gentle gravel slopes from the bases of mountains to desiccated communities throughout broad valleys. These human constructions jointly constitute a class of recent geologic features which, although small in volumetric aspect, is important in a proper archaeologic appraisal of the country as well as from a discerning physiographic perspective.

IGNEOUS ROCKS

Many kinds of igneous rocks outcrop in eastern Iran, including both basic and acidic types. Flows, plugs, and sills, which abound in the Eocene so-called "volcanic series" of the central deserts, are mainly basic.

Granite has been found in several places in northeast Iran. A small granite area, intrusive into limestones of possibly Jurassic age, occupies a central position in the massif of the Anti-Elburz range east of a limestone spur near Kasr-Firuz about 10 miles (16 km.) southeast of Tehran (Rivière, 1936, p. 279). A more extensive granite mass forms the center of the east end of the main Elburz axis in Kuh-i-Binalud and Kuh-i-Dizak south and southeast of Meshed. Similar granitic cores are known at a number of localities in the central Elburz axes. Granite mapped by Stahl (1895) at several places not far from the north flank of mountains bordering the Gurgan plains has not been seen by the writer or his associates. Granitic intrusives are reported by Reeves in his "volcanic belt" between Gunabad (Jumin) and Firdows (Tun). He also reports small granite areas in two localities within 70 miles (113 km.) southeast from Shahrud.

A considerable area of hard, dark shales and sandstones, a few miles west and northwest of Zahidan, apparently metamorphosed and cut by numerous quartz veins, has in its center a granite mass. Although the

age of the sedimentary rocks and that of the granite are unknown the shales are generally similar—even if somewhat harder, darker, and more intensely veined—to the Eocene deposits recognized throughout extensive areas on the north, northwest, and south. Thompson reports thin-bedded Eocene sandstones lying unconformably against this mass. He believes the granite to be identical in age with certain altered gneissic-granitoid rock ("possibly diorite") observed in two anticlines within 12 miles (19 km.) north from Iranshahr and capped by an altered basic igneous flow of probable Eocene age.

The Zahidan granite and the surrounding sedimentary rocks are cut by numerous basic dikes. Vredenburg (1901) reports diorite bosses and dikes from Kuh-i-Malik Siah. A small mass of coarsely granitic rocks was seen occupying the core of a south-trending anticline of Eocene shale southwest of Nosratabad-Sipi. This granite and the overlying Eocene shales are cut by numerous basic dikes (Pl. 12, fig. 3) just as they are near Zahidan.

In east-central Iran, Furon (1936) reported gneiss and amphibolite between Pusht-i-Badam and Rizab, and Schenck recognizes also schists, gneisses, and other rocks in the same region. In north-central Iran, in the Hashimabad anticline in a range northeast of the Darya-i-Namak (salt lake) at the west end of the Dasht-i-Kavir, phyllites and mica schists penetrated by granite dikes were seen by Mr. J. Nason Jones (De Böckh, Lees, and Richardson, 1929, p. 138). The same observer described aphanitic lavas, melaphyres, and trachytes—the whole series amounting to 1500 feet and associated with other igneous rocks—in a range to the southwest.

The igneous deposits of Afghanistan and northeast Khurasan were broadly assigned by Griesbach (1887, p. 102) to four different ages, as follows:

No.	Type	Age
4	Trachytes and rhyolites	Tertiary
3	Trap and syenitic granite	Eocene
2	Trap	Jurassic and "Neocomian"
1	Trap and melaphyre	Permian

Griesbach mentioned "syenitic granite" and "trap" dikes and bosses in Khurasan province. He stated that

"interbedded trap and melaphyre in the lowest beds of the plant series are well-seen in the northwestern extension of the Yaktan Range of Khorassan."

Schindler (1884) described the occurrence of well-known turquoise deposits associated with porphyries, greenstones, and metamorphic rocks at Madan in the mountains about 32 miles (52 km.) northwest from Nishapur, intruded between nummulitic limestone strata. Hedin (1918; 1927) published some excellent petrographic reports of the route of his traverse.

Tipper (1921, p. 61-62) described an "Upper Cretaceous volcanic series," 25 miles in breadth, comprising the Jamal Bariz (Kuh-i-Shah Savawan) range 13,000 feet in altitude, which rises northeast of the Bampur plain. The rocks are tuffs, agglomerates, and lavas, with occasional conglomerates, intruded by porphyry dikes. The same writer mentioned similar volcanic accumulations between Bam and Abariq. At Abariq the rocks are basic and rest with slight unconformity upon dark-gray "Hippuritic" limestones. Although there is no evidence that all Cretaceous volcanic rocks are of identical age, those near Abariq are believed to be Upper Cretaceous. Tipper's (1921, p. 195-197) attempted correlation with Vredenburg's "volcanic series" along the British frontier is not substantiated.

The known outcrops of igneous rocks in eastern Iran may be correlated in part with (1) granitic rocks of the Zahidan massif and anticlines near Iranshahr and Nosratabad-Sipi (age unknown) already described, and in part with (2) basic plugs, dikes, flows, and sills, of Upper Cretaceous to uppermost Tertiary age. The last-mentioned group comprises the so-called Tertiary "volcanic series" of northwest, north-central, and central-eastern Iran. In extreme eastern Iran these rocks have been mapped as far north as the Tehran-Meshed highway and as far south as Bam. They are bounded on the north by the tuffaceous deposits of the "green series" in the Elburz mountain front and in much of east-central Iran. The most noticeable intrusions south of the Zahidan massif are the recently extinct volcano of Kuh-i-Taftan (or Meh Kuh) and the sometimes-smoking Kuh-i-Bazman (Kuh-i-Naushada) with which local flows are reported associated.

In Seistan, both on the Iranian and Afghan sides of the frontier, within the limits of the more ancient lake bed, are a number of volcanic plugs, some of which are topographically notable. The rocks of Kuh-i-Khwaja (Huntington, 1905, p. 286) include:

1. Porphyritic dolerite
2. Fine-grained basalt
3. Dull brick-red, very porous andesite which is almost a pumice
4. Ash beds

Huntington (1907, p. 364) considers that the Seistan volcanoes broke out "during the latter part of the Quaternary era," but Schenck considers these igneous rocks pre-Quaternary.

Aside from these recent volcanoes, we know of few igneous rocks in the Eocene area of southeast Iran. Blanford (1876, p. 478-480) reported a small hill of trachydolerite abutting against slate northeast of the fort at "Aib-i-Kalagan" in the Dizak region and he mentioned volcanic rock in an area extending 8 miles (13 km.) east from "Abtar." Thompson and Hotchkiss mention a fine-grained dike, 80 to 100 feet in diameter, 20½ miles (33 km.) southeast from Khash, grading upward into porphyry and having an associated quartz vein which is considerably mineralized—the whole mass intruded into Eocene strata. Thompson likewise reports several dikes of black, fine-grained basic igneous rock which penetrate the Eocene beds and overlying conglomerates 5 miles (8 km.) northeast of the village of Karwandar.

Referring to the area along the central-eastern frontier north of Lat. 32° N. south of the road between Turbat-i-Haidari and Khaf and west of the highway from Turbat-i-Haidari to Birjand, Reeves in a report to Amiranian Oil Company, says that

"Igneous rocks predominate. . . . These consist largely of flows, breccias and tuffs, thousands of feet in thickness. Associated with extrusives are numerous intrusive bodies consisting of dikes, sills, volcanic necks, chonoliths and large bodies which may be laccoliths. These rocks appear to be derived from both acidic and ultrabasic magmas, the older being probably the more acidic. Igneous activity in the region evidently began in Cretaceous or earlier time and persisted to late Tertiary. Interbedded with these volcanics and derived from them are conglomerates, red shales, gypsiferous clays and water-worn tuffs."

This description is the usual sort of record available as to igneous rocks in much of eastern Iran. The collective evidences of volcanic activity are not confined to the area of this paper, however. Similar phenomena exist all the way from Turkey southeast across central Iran into British Baluchistan and even to the Indian Ocean near Karachi. Throughout this great area, 2500 miles long and 400 miles wide, the effects of intrusions are widespread; yet the visible formations are mainly tuffs and lavas having numerous interstratified sandy and calcareous beds which are likewise of great thickness and contain identifiable Eocene marine fossils.

Eruptive rocks are more extensive in some regions than in others, perhaps reaching greatest development in the area between the Dasht-i-Lut on the south and the Tehran-Meshed highway on the north, extending from Qum to the Afghan frontier. Their outside limits cannot be accurately defined, however. In Lat. 30° N. the southwest side may lie near Kerman but passes diagonally northwestward in the direction of Hamadan. Mountains south of Kashan carry 3000 to 5000 feet of rhyolite tuffs and intrusive rocks.

In eastern Iran little evidence has been collected for correlating igneous rocks. It is probable, however, that volcanic rocks in northeast Iran are not generally identical with basalts of the Dukhtar series in the

FIGURE 1. SURFACE EVIDENCES OF KANATS (ARTIFICIAL UNDERGROUND WATER CHANNELS)
Near Shimran, Tehran province.

FIGURE 2. ANCIENT TOWER (A. D. 997)
At Gunbad-i-Qabus, eastern Gurgan province, standing on a much older artificial mount.

FIGURE 3. WALLS OF ANCIENT CITY OF RHEY (Rhages)
5 miles south from Tehran, showing west end of Shah 'Abdul 'Azim Mountains to left.

South. Although this group of rocks has no clearly defined upper limit, and although not proved Eocene, Pilgrim (1924, p. 68-71) correlates these basalts with the Eocene flows first described by Vredenburg (1901) on the British frontier and again with the Deccan trap of India (Holland, p. 63-64). Thompson provisionally suggests a correlation of certain flows, tuffs, and sills in the Fahrej region, north of Bam, with Pilgrim's Upper Cretaceous volcanic rocks.

In the region between the Afghan border and the Zahidan-Meshed road Reeves mentions an upper "volcanic series" 5000 feet thick and a lower "sedimentary series" of 5000 to 6000 feet. The last mentioned is described as calcareous, green, sandy shales, having lenses of buff to black marine limestones totalling 1500 feet. This series grades laterally into maroon and splintery green gypsiferous shales and volcanic rocks. Apparently there was no consistent areal upper or lower limit to volcanic activity.

CONCLUDING STATEMENT

The compilation comprised in the present paper is not even approximately complete within any branch of the subject. It is merely intended as a step toward advancing the geologic knowledge as to eastern Iran so that data will be available for the use of future students of the region and for comparison with discoveries in other areas. Although a geologic map is here provided, the author has no intention of trying to provide a final map, for most of the localities remain in a state of imperfect knowledge. In order that the present work may be of greatest possible utility to workers in the field, the rendering of references to isolated collections and the conclusions derived therefrom have been deliberate; these were the essence of the recent reconnaissances, and future geologic workers must build upon them.

In the field of literature likewise the author realizes that valuable references may be missing, for the task of perusing everything written on such a considerable area makes some stopping point necessary. The appended bibliography of the geology of eastern Iran enables reference to the literature consulted, and the index to localities helps to find the approximate map location of places mentioned.

In the course of the Iranian field work it was not possible for the Company's paleontologist to study all fossils collected by field geologists, and some forms may remain indefinitely unidentified. Neither is it expected that identification and assignment of ages made herein are in all cases the last word. The present paper is necessarily issued at a time when the author is free to prepare it, and delay might have prevented its completion. The author hopes and anticipates that papers

will appear by paleontologists and field geologists to elaborate many matters.

Collections made during the explorations sponsored by Amiranian Oil Company have been filed in the Museum of the Department of Geology at Stanford University, California, as well as in Tehran, and are thereby available for study. Numerous new species are now being described by several specialists, and these forms, as well as other accumulated data, constitute a basis for contributions to the literature of which the present paper may be considered as furnishing a necessary background.

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GEOGRAPHICAL INDEX

The localities are taken from the Survey of India maps (Scale 1:1,000,000). In the case of mountains a central point of the range is used; in the case of rivers the position of the mouth is taken (except, in the case of the Hari Rud, the position noted is the point where the river leaves Iran). Any of the names in this list are subject to the usual inaccuracies of published maps; none here are determined astronomically. The word "Rud" signifies River; "Kuh" means Mountain

or Mountains (or, in some cases "Pass"); "Kavir" means "Desert." The reference meridian is that of Greenwich.

Spelling used herein	Lat. N.		Long. E.		Other known spellings
Abariq	29°	19′	57°	55′	
Abbasabad	35°	56′	53°	..	
Abbasabad	36°	21′	56°	22′	
Aineversan	35°	39′	52°	9′	
Aitamir	37°	51′	55°	25′	
Ala Dagh (mountain)	37°	15′	57°	30′	
Alamol	36°	12′	51°	16′	
Al-busa	26°	37′	55°	5′	
Amaria	36°	30′	55°	..	
Anarak	33°	21′	53°	40′	
Anti-Elburz (Mts.)	35°	40′	51°	35′	
Arasun	33°	30′	54°	56′	
Ashraf	36°	43′	53°	35′	Achref, Aschref, Aschraf
Askhabad	37°	58′	58°	23′	Ashqabad, Askabad, Eshqabad
Aspak	33°	17′	57°	19′	
Atrek (river)	37°	28′	54°	5′	
Azerbaijan (Province in N. W. Iran)	..	..	..	..	Azarbaijan
Babol	36°	34′	52°	45′	Barfarush
Badamu (range)	30°	19′	56°	50′	
Badaralu	37°	31′	57°	6′	Badr-Ali
Bafq	31°	35′	55°	25′	
Bakhtiari (Mts.)	32°	30′	49°	..	
Bam	29°	6′	58°	20′	
Bampur	27°	12′	60°	28′	
Bandar 'Abbas	27°	10′	56°	17′	Bender Abbas, Bunder Abbas
Bandar-Shah	36°	56′	54°	6′	
Behli Dagh (Mts.)	37°	38′	55°	50′	
Bend-i-Burida (pass)	36°	4′	52°	12′	
Besh-Khardesh (shrine)	37°	24′	57°	17′	
Biabanak	33°	20′	55°	3′	Baiaza
Bijistan	34°	32′	58°	10′	
Birinti (gorge)	27°	17′	57°	15′	
Birjand	32°	52′	59°	14′	Birdjand
Bujnurd	37°	29′	57°	20′	Boujnurd
Chahar-deh	36°	27′	54°	18′	
Chahar-deh	33°	44′	56°	47′	
Chahbar	25°	18′	60°	37′	Chahbehar
Chah-i-Shirin (spring)	35°	28′	53°	56′	
Chalus	36°	40′	51°	30′	
Chalus Rud	36°	40′	51°	30′	
Chehil-duktaran	30°	38′	60°	38′	Chehel-dokhtaran
Chehil-pai	32°	4′	57°	23′	
Chinaran	36°	38′	59°	6′	Tchinaran
Clarence Strait	27°	..	56°	..	
Dachit	37°	16′	58°	58′	
Damghan	36°	10′	54°	22′	Demghan
Darband	37°	16′	56°	51′	
Darbend-i-Sar	36°	..	51°	28′	
Daryacheh-i-Namakzar (salt lake)	34°	..	60°	30′	Namaksar
Darvazeh-i-Nadir (pass)	29°	49′	59°	53′	
Darya-yi-Namak (salt lake)	34°	40′	51°	30′	
Dasht-i-Kavir (desert)	35°	..	56°	..	Desht-i-Kevir
Dasht-i-Lut (desert)	30°	..	59°	..	Desht-i-Lut
Deh-i-Mohammed	33°	58′	56°	56′	

Spelling used herein	Lat. N.	Long. E.	Other known spellings
Deh-i-mulla	36° 17′	55° 47′	
Delitchai (valley)	35° 31′	52° 29′	
Demavend	35° 43′	52° 3′	Demavand
Demavend (Mt.)	36° 2′	52° 5′	Kuh-i-Demavand
Deredges	37° 28′	59° 7′	Muhammadabad
Diktash	35° 45′	53° 10′	Diktasch
Diwan-Chah	29° 55′	60° 50′	
Dizak	27° 20′	62° 21′	
Doab	36° ..	53° ..	
Dorun	35° 58′	51° 27′	
Doshan-tepeh	35° 41′	51° 30′	
Duhak	33° 17′	57° 30′	
Duruna	35° 10′	57° 17′	
Elburz (range in N. Iran)	.. ..	.. ..	Alburz, Elbourz, Alborz
Emaret	36° 20′	52° 24′	
Fahreh	27° 13′	60° 43′	Fehruj
Farimun	35° 43′	59° 53′	Ferimoun
Fashand	35° 55′	51° 31′	Faschand
Ferahzad	35° 47′	51° 21′	Farahabad, Farahzad
Firdows	34° 1′	58° 9′	Tun, Toun, Ferdous
Firuzkuh	35° 46′	52° 45′	Firouzekouh, Firooz Koh
Firuz Kuh (Mts.)	35° 50′	52° 50′	Firouze-Kouh
Fulad-mahale	36° 2′	53° 45′	Foulad-Mahaleh, Fulad-Mahalleh
Galeh-zaboli	27° 8′	61° 41′	Magas, Qaleh-zaboli
Garm-ab	37° 45′	56° 18′	
Gaud-i-Zirrah (salt lake)	29° 45′	62° ..	
Germab	36° 1′	51° 40′	
Germah	37° 2′	56° 21′	
Ginau (range)	27° 25′	56° 10′	
Gudack (pass)	35° 52′	52° 53′	Firuz Kuh
Gudar-i-Gishu (pass)	28° 7′	58° 50′	Gishu (pass)
Gulshan	33° 37′	56° 55′	Tabas, Golshan, Tebbes
Gunabad	34° 20′	58° 42′	
Gunbad-i-Qabus	37° 17′	55° 17′	Gumbad-i-Kabus, Goumbade-Ghabouse, Goumbad-i-Kabus
Gurgan	36° 50′	54° 29′	Asterabad, Gorgan, Astrabad
Gurgan (province in N. Iran)	.. ..	.. ..	Asterabad, Gorgan, Astrabad
Gurgan (river)	36° 59′	54° 5′	Gorgan
Gurgan Camp No. 1	37° 37′	55° 35′	(temporary only)
Gwadar	25° 7′	62° 20′	
Hablé Roud	35° 22′	52° 12′	
Hamadan	34° 51′	48° 11′	
Hamun-i-Helmund (lake)	31° 30′	61° 20′	Lake Helmund
Hamun-i-Mashkel (salt lake)	28° 15′	63° ..	
Hari Rud (river)	36° 35′	61° 12′	Heri Rood
Hasanabad	30° 55′	60° 26′	
Hasanabad	35° 55′	54° 20′	
Hauz-i-Khan	32° 10′	57° 29′	
Hauz-i-Panj	31° 3′	56° 58′	
Hauz-i-Sheikh	32° 14′	57° 31′	
Helmund (lake)	31° 30′	61° 20′	Hamun-i-Helmund
Helmund (river)	31° 28′	61° 25′	
Heras (valley)	36° 40′	52° 22′	Harhas
Herat	34° 20′	62° 9′	
Hormuz (island)	27° 4′	56° 28′	
Hour (valley)	36° 10′	48° 18′	Nur

Spelling used herein	Lat. N.	Long. E.	Other known spellings
Hurmuk	29° 59′	60° 51′	
Ichan	26° 21′	60° 6′	Hichan
Imam-Hassan	34° 27′	45° 45′	
Imam-Zadeh-Hashim (Mts.)	35° 47′	52° 2′	Imam-Zadeh-Hachim
Iranshahr	27° 13′	60° 43′	
Isfahan	32° 40′	51° 42′	Ispahan
Isfadnak	27° 6′	62° 50′	
Jaghatai (Mts.)	36° 30′	57° ..	
Jahbun	35° 40′	52° 13′	Jabon
Jajarm	36° 58′	56° 22′	
Jajrud (valley)	35° 15′	51° 30′	Jajarud, Djadjrud
Jalou	36° 8′	51° 54′	Yalu
Jalq	27° 37′	62° 43′	Jalk
Jam (valley)	35° 8′	61° 5′	Djam
Jamal Baris	28° 25′	58° 30′	
Jandaq	34° 2′	54° 27′	Jandak, Djandaq
Janet-abad	35° 35′	61° 8′	Jannatabad
Jarika	30° 18′	60° 46′	
Julfa	38° 54′	45° 36′	Djoulfa
Kadamgah	36° 6′	59° 2′	Ghadam-Gar, Qadamgah
Kahriz	34° 48′	60° 49′	Kariz, Keriz
Kalateh	36° 23′	54° 13′	
Kalateh	36° 56′	58° 28′	
Kalat-i-Nadiri	37° ..	59° 45′	Kalat
Kalmarz	33° 28′	56° 16′	Qalmarz
Kalpurkan	27° 14′	62° 32′	
Karaguli Dagh	37° 37′	55° 48′	
Karaj (valley)	35° 15′	51° 30′	Keredj
Karwandar	27° 52′	60° 44′	Karvanda
Karwandar (valley)	27° 9′	60° 45′	
Kashan	33° 58′	51° 29′	Cashan, Kaschan
Kashmar	35° 12′	58° 27′	Turshiz, Sultanabad
Kasr-Firuz	35° 40′	51° 31′	
Kasr-i-Shirin	34° 31′	45° 34′	
Kazvin	36° 15′	50° ..	
Kerman	30° 7′	57° 5′	Kirman
Khaf	34° 33′	60° 8′	Roui
Khamir	26° 57′	55° 36′	
Khanu	27° 57′	57° 48′	
Khash	28° 14′	61° 15′	Khwash, Vasht
Khur	33° 47′	55° 3′	Khour
Khurasan (province in N. E. Iran)	.. ..	.. ..	Khorasan, Korassan
Khurünaq	32° 21′	54° 41′	
Kirtaka	29° 28′	61° 25′	
Kohrud Mts	33° 38′	51° 28′	Kheriz-Khohroud
Kopet Dagh (Mts.)	38° 30′	57° ..	
Kudjour (valley)	36° 35′	51° 49′	Kojur
Kuhbanan	31° 23′	56° 19′	
Kuh-i-Bampusht	26° 45′	62° 30′	
Kuh-i-Bazman	28° 5′	60° 3′	
Kuh-i-Binalud	36° 20′	59° ..	
Kuh-i-Birg	27° 30′	61° 30′	
Kuh-i-Dizak	35° 15′	60° 15′	
Kuh-i-Hazar Masjid	36° 45′	59° 30′	
Kuh-i-Khwaja	30° 55′	61° 15′	
Kuh-i-Malik Siah	29° 52′	60° 53′	
Kuh-i-Naiband	32° 27′	57° 20′	
Kuh-i-Namak	27° 34′	56° 17′	
Kuh-i-Namak	34° 45′	50° 45′	
Kuh-i-Shah Savaran	28° 8′	58° 50′	

Spelling used herein	Lat.	N.	Long.	E.	Other known spellings
Kuh-i-Shutari	33°	30′	57°	20′	
Kuh-i-Siah	31°	29′	60°	52′	
Kuh-i-Sultan	29°	7′	62°	45′	
Kuh-i-Taftan	28°	37′	61°	8′	
Kunji Rud	29°	50′	59°	57′	
Kurd-Mahalleh	36°	49′	54°	7′	
Lake Helmund	31°	30′	61°	20′	Hamun-i-Helmund
Lar (river)	35°	53′	52°	5′	Lore
Leshkerek	35°	47′	51°	42′	Lashgarak
Lutfabad	37°	32′	59°	21′	
Madar-i-Shahr	33°	12′	50°	49′	
Maiamai	36°	25′	55°	45′	
Makran (province in S. E. Iran)	..	..	..	..	Mokran, Mekran
Maluman	35°	12′	54°	37′	
Maraveh-tepeh	37°	56′	55°	59′	
Mazandaran (province in N. Iran)	..	..	..	..	
Menjil	36°	42′	49°	28′	Manjil
Merou	37°	30′	57°	14′	
Meshed	36°	17′	59°	37′	Meched, Mashed, Mashhad
Mirjawa	29°	2′	61°	26′	
Miyandasht	36°	27′	56°	3′	Miandasht
Mobarecke	35°	48′	51°	56′	
Morghzar	37°	2′	56°	45′	
Muhammedabad	37°	28′	59°	7′	Mohammed-Abad
Murkh-i-Surkh	30°	39′	60°	45′	
Musha	35°	46′	52°	3′	Mushe
Muzduran	36°	8′	60°	35′	Muzuran
Muzduran Pass	36°	7′	60°	34′	Muzuran (Pass)
Naibandan	32°	21′	57°	34′	Naiband
Namaha	36°	27′	54°	17′	
Namakzar (salt lake)	30°	30′	58°	30′	
Nastanj	33°	57′	56°	37′	
Neh	31°	32′	60°	3′	
Nika	36°	40′	53°	19′	Nikka, Nikah, Neka
Nika Rud	36°	51′	53°	12′	Nikka Roud
Nisa	36°	3′	51°	18′	
Nishapur	36°	12′	58°	50′	Nichapour, Nishabourg
Nok-Kundi	28°	50′	63°	45′	
Nosratabad-Sipi	29°	53′	59°	58′	Nasratabad-Sipi
Padagi	30°	2′	60°	50′	
Palang Darwazeh	36°	3′	51°	54′	Palangvase
Panj (range)	29°	53′	56°	5′	
Paropamisus (Mts.)	35°	..	61°	40′	Siahbubak (range)
Pasgaleh	35°	50′	51°	23′	
Pelour	35°	53′	52°	4′	Pulur
Persepolis	29°	57′	52°	54′	Takht-i-Jamshid
Pouhl	36°	20′	51°	35′	
Pozug	25°	57′	60°	11′	
Pul-i-Khvatun	35°	57′	61°	7′	Puol-i-Khatun, Pol-e-Khatun
Pusht-i-Badam	33°	2′	55°	30′	
Pusht-i-Kuh	33°	..	47°	30′	
Qain	33°	42′	59°	11′	Kain
Qaleh-zaboli	27°	7′	61°	40′	Magas, Galeh-zaboli
Quchan	37°	6′	58°	30′	Kuchan
Qum	34°	39′	50°	54′	Kum, Koum, Koom, Qoum
Radkan	36°	40′	54°	12′	Radkhan
Radkan	36°	51′	59°	..	
Rasht	37°	15′	49°	37′	Resht
Ravar	31°	14′	56°	54′	Rawer

Spelling used herein	Lat.	N.	Long.	E.	Other known spellings
Rhey	35°	36′	51°	28′	Rey, Rei, Rhe, Rhages
Rishm	35°	15′	54°	31′	Gulak, Reshm, Rashm
Rizab	32°	28′	54°	59′	
Robat	37°	55′	57°	42′	Rabat, Rabad
Robat-i-Khan	33°	22′	56°	2′	
Rudahan	35°	45′	51°	53′	Roudehen
Rudkhana-Duzdan (valley)	27°	17′	57°	13′	
Rum	33°	26′	59°	11′	Roum
Sabzawar	36°	12′	57°	39′	Sabsavar, Sabzevar, Sebzewar
Saghand (caravanserai)	32°	33′	55°	12′	
Saidabad	35°	40′	52°	26′	
Saindak (Baluchistan)	29°	16′	61°	35′	Sajindek
Samnan	35°	33′	53°	23′	Semnan, Simnan
Sandadio	34°	57′	58°	5′	
Sari	36°	35′	53°	5′	Sarei
Sar-i-Asiab	30°	32′	56°	58′	
Sar Su (River)	37°	30′	55°	37′	
Sefid-abeh	30°	52′	60°	39′	Safaidawa, Sefidaveh
Seistan (region)	31°	..	61°	..	Sistan, Seestan
Sepaieh Mt	35°	40′	51°	39′	
Serakhs	36°	32′	61°	10′	
Seruman	33°	38′	54°	25′	
Shahabad	37°	28′	56°	48′	Chah-Abad
Shah 'Abdul 'Azim	35°	36′	51°	27′	Shahr-i-Rei
Shah 'Abdul 'Azim Mts	35°	36′	51°	30′	
Shahi	36°	27′	52°	54′	Aliabad
Shahr-i-Babak	30°	7′	55°	9′	
Shah-Kuh	36°	30′	54°	30′	
Shah Kuh (pass)	36°	37′	54°	42′	
Shah-kuh-pain	36°	34′	54°	27′	
Shahrud	36°	26′	55°	2′	Schahrud, Shahrood
Shamshak	36°	..	51°	29′	Chemchek, Schemschek
Shamshir-i-Quli	33°	30′	47°	10′	
Shelagh River	29°	48′	61°	31′	
Shimran	35°	47′	51°	23′	Chimran, Schemran
Shiraz	29°	37′	52°	33′	
Shir Kuh	31°	37′	54°	5′	
Siah Kuh	31°	29′	60°	52′	
Siah Kuh	34°	37′	52°	17′	
Sianeh Kuh	27°	15′	62°	45′	
Sib	27°	15′	62°	5′	
Soh	33°	26′	51°	28′	
Surukhs	36°	14′	60°	40′	Shurukhs, etc.
Tajan Rud	36°	50′	53°	5′	
Talar (valley)	36°	46′	52°	50′	
Tehran	35°	40′	51°	25′	Teheran
Tehran (province in N. Iran)	..	..	..	..	Teheran
Tochal (Mt.)	35°	54′	51°	23′	
Turbat-i-Haidari	35°	16′	59°	13′	Tourbet-icha-Khan (?)
Turbat-i-Shaikh Jam	35°	13′	60°	39′	Tourbet-i-Cheikh Djam, Tourbet-ishak-Khan
Turut	35°	25′	55°	7′	Turud, Tourout
Uzbeg Kuh	34°	40′	56°	59′	Uzbaku
Vahne	36°	..	52°	12′	
Valiabad	36°	15′	51°	17′	
Yezd	31°	54′	54°	24′	Yazd, Jezd
Zabol	31°	1′	61°	30′	Nasratabad, Shahr-i-Zabol
Zagros (Mts.)	33°	30′	47°	..	

Spelling used herein	Lat.	N.	Long.	E.	Other known spellings
Zahidan	29°	29′	60°	52′	Duzdab (former name), Zahedan
Zaidar	36°	25′	55°	49′	
Zaigun	35°	58′	51°	34′	
Zarin Kuh	35°	43′	52°	17′	Zarinkouh
Zelim Rud	36°	22′	53°	13′	
Zindan (range)	27°	21′	57°	8′	
Zurabad	35°	42′	61°	7′	Zouhr-Abad

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WEATHERING OF THE JERSEYAN TILL

BY PAUL MAC CLINTOCK

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ABSTRACT

Since limestone pebbles are virtually absent because of great age of the drift, and soil profiles are not diagnostic because slope wash on rolling country has cut off the upper horizons, the amount of weathering which the gneissic pebbles have suffered is used as a criterion of age. The pebbles, dug from undisturbed till 4 feet below the surface, were classified with respect to the amount of weathering each one exhibits. To give a starting point for post-Jerseyan weathering a similar analysis was made of the gneissic pebbles in fresh Wisconsin till a few miles to the north. By comparing the curves plotted from these data it appears that there are two and possibly three divisions within the drift sheet. In a northern belt of drift stones are approximately 20 percent more weathered than those in the Wisconsin, whereas in a southern belt they are 30 percent more weathered. The possible third type, 12 percent more weathered, occurs near Budd Lake.

INTRODUCTION

LOCATION, EXTENT, AND CHARACTER OF DRIFT

Pre-Wisconsin drift is found in a belt 20 miles wide south of the Wisconsin terminal moraine in New Jersey between the Delaware River

and the Watchung Mountains, an east-west distance of 35 miles. Within this belt drift occurs in approximately 65 large and small patches with only scattered erratics between them. These patches occupy valley bottoms, hill slopes, or hill tops. The thickness of the drift, ranging up to 20 feet or more is most commonly 8 or 10 feet. The drift itself is partly till and partly gravel. The till in the northern part of this area, lying on pre-Cambrian and Paleozoic rocks, has a buff, silty clay matrix, whereas that in the southern part, lying on red-brown Triassic shale, has a red-brown clayey matrix. This red-brown clay has stained the stones in the till of the southern part to a rusty brown, which gives them a more weathered appearance than those in the drift of the northern part. Various proposals have been made as to the age and subdivision of this pre-Wisconsin drift.

PREVIOUS WORK

Cook (1880) considered the glacial deposits south of the terminal moraine older than the moraine. McGee (1888) believed that the deposits outside the terminal moraine in the Susquehanna and Delaware valleys were the results of marine submergence accompanying a glacial invasion and were much older than the terminal moraine. Salisbury (1902) reported a 10-year study of glacial deposits in New Jersey. He mapped and described extra-morainic drift as mostly much older than the moraine but considered a narrow fringe of drift just beyond the moraine intermediate in age. Salisbury (1902, p. 781) states:

> "On the whole, most of the extra-morainic drift seems to correspond more nearly with the drift of the Kansas epoch than with that of any other, so far as the physical and chemical condition of the drift, and its topographic position, warrant a conclusion. On the other hand, it is not to be lost sight of that in the proximity of the moraine, and at a few other points, there is drift which looks distinctly less old than most of that which lies outside the moraine. Some of this is doubtless of Wisconsin age. Perhaps some of it may be of an age intermediate between the Wisconsin and the oldest drift."

But in the Raritan folio Bayley, Salisbury, and Kümmel (1913) map all the extra-morainic drift as one drift sheet—the Jerseyan. Also, in the New Jersey State map the extra-morainic drift is not subdivided. Furthermore, Wright (1892, 1910) contended that the evidence for much greater age for the extra-morainic drift was inconclusive. In the detailed work of the soil survey of the area by the Federal Bureau of Soils in cooperation with the State Department of Conservation and Development (Patrick, *et al.*, 1920, 1923) no division of the pre-Wisconsin drift was recognized though the matter was given careful consideration.

The question of the age of the pre-Wisconsin drift was more recently presented by Leverett (1934) who revived Salisbury's early suggestion that there were two pre-Wisconsin drifts in New Jersey. He called

the oldest drift Kansan and the intermediate drift Illinoian. However, he extended the area of Salisbury's intermediate drift to include almost all the drift in the Highlands as well as that on Triassic at Bernardsville and Basking Ridge. His opinion that the intermediate drift is younger than the Jerseyan (Kansan) is based on three lines of evidence: (1) The Illinoian drift has morainal topography in the Saucon valley and near Emous, south and west of Bethlehem, Pennsylvania. (2) Limestone pebbles are found in this drift at depths of about 12 feet below the surface. (3) This drift is found at or near the bottoms of the present valleys, whereas the Jerseyan is found only on uplands below which valleys have been cut in post-Jerseyan time. He also stresses the fresher appearance of the drift itself. While the present author is largely in agreement with Leverett, it is still desirable to point out that his lines of evidence are open to other possible interpretations. The drift near Bethlehem which shows "morainal topography" lies on a soluble limestone containing many sink holes, so what appears to be morainal topography might just as easily be the result of solution and collapse in the underlying limestone.[1] The presence of limestone pebbles in some places within 12 feet of the surface might be due to impervious overlying material, to special ground-water conditions as in a poorly drained profile, or to removal of overlying material by erosion. Many examples of apparently shallow leaching are thus explained in the older drifts of the Mississippi Valley region. The presence of drift in the Highland section at or near the bottoms of present valleys might be attributed to the less rapid erosion of streams in this section compared with those on the soft rocks of the Triassic Piedmont Lowland. Furthermore, while in the Triassic section most of the till remnants do occupy upland sites, there are some notable exceptions, as near Lamington, where till is found down to the bottom of the valley of the Lamington River.

The current study has been made to see if another criterion of age, based on purely objective and statistical data, might be of significance. It involves a study of the weathering of pebbles in the drift, collected with great care to give as nearly homologous conditions as possible. The most widespread and useful kind of pebble in the drift for the present study is that of gneiss or pegmatite.

ACKNOWLEDGMENTS

Field work was financed by a grant from the Department of Geology, Princeton University. David Brown acted as the able and helpful field assistant. The author takes particular pleasure in acknowledging

[1] The method used in the current study shows the drift exposed in the railroad cut in the southern outskirts of Bethlehem to be weathered as much as any of the exposures of the oldest drift in New Jersey.

his gratitude for discussion and criticism to the 20 members of the field conference of glacial geologists to whom he had the pleasure of demonstrating the problem of the weathering of the Jerseyan Drift in May 1939.

EVALUATION OF WEATHERED MATERIAL

RATE OF WEATHERING

The rate of weathering is affected by several well-known conditions.

1. The lithology of the drift, of course, is of primary importance. In humid climates limestone and igneous material decay relatively rapid, while quartzite and sandstone endure. Even shale, a few feet below the surface, survives better than igneous stones. In judging the age of any particular exposure of drift, therefore, it is necessary to ascertain its lithology.

2. The permeability of the drift to downward percolating waters plays so important a role that gravel is weathered many times faster and deeper than till. Near Basking Ridge, White House, and Potterstown are exposures of gravel with the igneous stones badly rotted to depths of 12 to 15 feet. Nearby exposures of till in similar topographic position are strikingly fresher at this depth. However, there is an important exception to this generalization. Where water percolates too rapidly through very porous gravel it may fail to produce as much weathering near the surface as it does farther down where the stones are more continuously wet. This is true of Basking Ridge where at a depth of 2 feet the stones are perceptibly fresher than those at 10 feet (Pl. 1, fig. 1). The same principle in a slightly modified form applies to the weathering of the Wisconsin outwash gravel deposits of the Delaware Valley. At Carpentersville the gravel is leached of its calcareous material to a depth of about 6 feet, below which it is normally calcareous. But lenses of silt at depths of 8 to 15 feet are leached though they are both overlain and underlain by sandy gravel which effervesces freely with acid. It might have been assumed that the fine material, being less permeable, would have been leached less rapidly than the coarse. But the opposite is true and, aside from the fact that the calcareous material may have originally been in smaller particles, seems to be due to greater specific retention. Water staying in contact with the soluble material longer seems to have leached it more. A few miles to the south in the pit at Riegelsville, Pennsylvania, a 40-foot exposure shows in its upper part 6 to 7 feet of gravel on 3 to 4 feet of silt. Both the upper gravel and the silt are leached to a total of 11 feet. This is an unduly great amount for Wisconsin material and has been called Illinoian by some. If it is considered, however, in

FIGURE 1. MUCH WEATHERED GRAVEL 10 FEET BELOW SURFACE IN BASKING RIDGE KAME
Igneous stones are crumbly, quartzite hard.

FIGURE 2. EXPOSURE OF DRIFT ON HILLTOP 1 MILE WEST OF POTTERSTOWN

GRAVEL IN THE KANSAN DRIFT

FIGURE 1. ROADSIDE EXPOSURE OF DRIFT 2 MILES SOUTHWEST OF DOVER

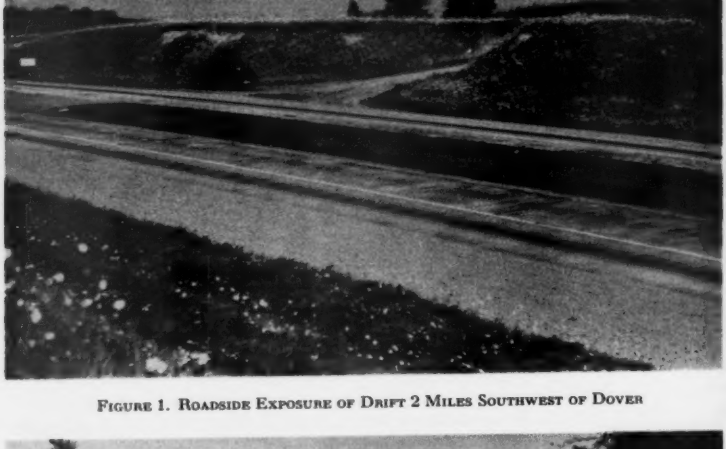

FIGURE 2. ROLLING COUNTRY ON SCHOOLEY MOUNTAIN 1 MILE NORTHWEST OF BUDD LAKE

TYPICAL OCCURRENCES OF TILL

the light of evidence from the Carpentersville pit, that the leached silt zone lay at the bottom of the normally leached gravel zone the exceptional depth of leaching is explained, and the Wisconsin age still retained. Mr. Chauncey Holmes, during a field conference, proposed another explanation of the leached silt layers in the Carpentersville pit. He suggested that during the aggradation of the valley train by melt water from the ice edge farther up the valley there may have been times when heavy rains washed silty well-weathered soil material from adjacent valley slopes out on the surface of the aggrading valley train. Later more outwash may have covered the layer of weathered silt. Detailed study of the silt layers will doubtless yield the true explanation of the phenomena. For the present purposes it is sufficient to point out the need for caution in the interpretation of weathering of gravel deposits.

3. The topographic position is likewise of considerable significance, for an upland position, well above the water table, makes for free downward percolation of the weathering solutions (Pl. 1, fig. 2). It follows that a position, such as on a lowland or the middle of a broad flat, where downward percolation is retarded, results in shallow and less advanced weathering. The soil scientists speak of the first as well-drained conditions (well-drained profile) and the latter as poorly drained conditions (poorly drained profile). There is an optimum rate of penetration at which maximum weathering takes place.

4. The role of climate in weathering is fairly well known. Warm moist conditions, favoring rapid weathering, commonly result in lateritic iron-rich soils. But on the other hand a cool climate may indirectly cause rapid weathering by means of the humic acids left unoxidized at the lower temperatures. The iron particularly forms relatively soluble organic compounds and is carried downward to leave a podsolic soil.

The soils on the pre-Wisconsin drift in New Jersey are now classified as belonging to the gray-brown group, having characters intermediate between the laterites and the podsols.[2] The record of the Pleistocene drift sheets shows that during the formation of the soils of this region the climate has fluctuated from that of humid subtropics through steppe to tundra and back again. This fluctuation has been repeated with each glacial and interglacial period. At least some of the characters of the soils, therefore, were produced under climate other than that of the region today. The lateritic character may well be inherited from the last warm humid interglacial climate, whereas the podsolic one may have been produced under periglacial climate. Evi-

[2] In detail there are at present certain types, such as the Lakewood Sandy Loam which is podsolic and others which show lateritic characters.

dence suggests that the upper part of some of the soils in the nonglaciated part of the State is podsolic and the lower part lateritic.

RATE OF SLOPE WASH

Slope wash carries away the uppermost part of the mantle rock. If this wash keeps pace with or exceeds weathering there will be no soil. The soil profile formed on glacial drift can be used to estimate the age of the drift only if there has been very little or no loss by slope wash or if the rate and amount of such loss is known. Thus far the latter information is not at hand in the area of the pre-Wisconsin drift in New Jersey. Slope wash on the rolling topography has everywhere cut away the upper part of the profile as it was being formed so that only immature ones now remain. Although the present soils are composed of partly weathered material they lack well-developed soil horizons.

METHOD OF COLLECTING DATA

Since limestone pebbles have been almost entirely leached out of the pre-Wisconsin drift, this criterion of depth of leaching cannot be used effectively. Likewise, since there are no flat areas to preserve complete soil profiles, the depth of weathering furnishes imperfect evidence as to age.

One of the most widespread and abundant constituents of the drift is the igneous material. For the purpose at hand the most useful type proved to be the medium-to-coarse-grained gneisses and pegmatites, which are practically ever present in the drift of the area. Since in each exposure the pebbles are weathered to varying degrees it was necessary to collect a large number in order to estimate the average degree of weathering. Obviously many of the stones were already partly weathered when picked up and deposited by the ice sheet. To ascertain the extent to which such stones might have been already weathered a study was made of fresh Wisconsin till which lies only a few miles to the north of the older drift. (*See* Table 1.) Within the area of the older drift, sites were selected on uplands having as nearly as possible the same surface slope in order to approximate similar topographic position. Pebbles 1 to 2 inches in diameter were dug out of the till at a uniform depth of 3½ to 4 feet below the surface and below the pan or "B" horizon of the soil. Care was taken to collect every stone of this size, even though badly decayed. Stones picked up on the surface of an exposure such as a road or railway cut did not give the true picture because frosting and rain wash had disrupted and carried away the greatly weathered stones. It was found unsafe to judge the amount of weathering by inspection of only the surface of the exposure. Where the drift is gravelly or sandy the amount of

weathering is noticeably greater than where it is clayey till, so that records from such porous places had to be set aside. There is also a considerable area of drift northeast of Phillipsburg which contains so few igneous pebbles that the pebble analyses are of no value in the present study. Furthermore, on slopes below outcrops of gneiss it was thought that solifluctional movement may have contaminated the record. Since the stations near High Bridge and near Tabor are of this nature they are given little weight in this discussion.

SAMPLE LOCALITIES

Sample localities are as follows:

Anderson—1 mile west. Roadside cut 8 feet, yellow-brown till.
Beattystown—half a mile northeast. Roadside cut 4 feet, yellow-brown till.
Bethlehem—Railroad cut in southern outskirts of city; exposes 30 feet of yellow-brown till; flat upland where samples were collected at 4 feet below surface.
Budd Lake—1 mile west. Gravel pit at brow of flattish upland; till exposed on north face of pit.
Denville—1 mile southwest. Road cut 8 feet, yellow-brown till at brow of flat upland.
Dover, SW.—2 miles southwest. Road cut 8 feet deep in yellow-brown till.
Dover, S.—1½ miles south. Road cut 10 feet in yellow-brown till at brow of flattish upland.
Dover, SE.—2 miles southeast. Road cut 4 feet deep in yellow-brown till.
Flanders—half a mile east. Exposes 10 feet of yellow-brown till on weathered gneiss in abandoned quarry.
Hackettstown—half a mile west. Roadside cut 8 feet, yellow-brown till.
Hampton—1½ miles northwest. Road cut 4 feet in yellow-brown till.
High Bridge—a quarter of a mile northwest. Roadside cut 8 feet, of yellow-brown till.
Lamington—half a mile west. Roadside cut 8 feet, of red-brown till.
Little York—half a mile south. Roadside cut and a little gully 10 feet of red-brown till.
Mendham—3 miles west. Excavation for a basement exposes 5 feet of dark, yellow-brown till on Martinsburg shale.
Middle Valley—1 mile east. Roadside cut 7 feet of yellow-brown till.
North Branch—1 mile west. Roadside cut 8 feet of red-brown till on flattish upland.
Oxford, W.—2¼ mile west-southwest. Road cut 8 feet in yellow-brown till, on gentle slope at upland level.
Oxford, E.—1 mile north-northeast. Road cut 5 feet in yellow-brown till on gentle slope.
Pattenburg—1 mile west. Roadside cut at top of hill 10 feet of red-brown till mixed with yellow-brown till in irregular masses.
Peapack—2 miles southwest. Roadside cut 4 feet deep in red-brown till at brow of flat upland.
Pennwell—One-quarter of a mile west. 8-foot road cut in yellow-brown till.
Readington—1 mile east. Roadside cut 8 feet in red-brown till at edge of wide gentle upland.
Somerville—2½ miles north. Road cut 5 to 8 feet red-brown till.
Tabor—1 mile southwest. Road cut 7 feet deep in yellow-brown till, gently sloping upland.
Washington—2 miles northeast. Roadside cut 15 feet, yellow-brown till in flattish upland.

CLASSIFICATION OF SAMPLES

For the purposes of the present study it has been found practical to classify the gneissic stones into five groups representing five degrees of weathering; (1) 0-20 percent weathered; (2) 20-40 percent weathered;

(3) 40-60 percent weathered; (4) 60-80 percent weathered; and (5) 80-100 percent weathered. The amount of weathering which each stone has suffered is a matter of personal judgment. It is striking,

TABLE 1.—*Jerseyan till: Tabulation of weathering data*

Locality	Number of stones	Percentage weathered						Notes
		0–20	20–40	40–60	60–80	80–100	Mean	
1. Anderson	33	0	3	27	39	27	66	
2. Beattystown	48	0	4	42	44	10	63	
3. Bethlehem	84	0	0	6	44	50	79	
4. Budd Lake	156	0	9	65	23	3	54	
5. Denville	56	0	0	42	43	15	65	
6. Dover, SW	152	0	1	32	48	18	66	
7. Dover, S	174	0	3	36	41	20	66	
8. Dover, SE	130	0	2	32	48	18	66	
9. Flanders	104	0	4	41	33	18	61	
10. Hackettstown	101	0	8	38	45	10	62	
11. Hampton	88	0	1	45	42	14	65	
12. High Bridge	287	0	6	31	40	23	66	Solifluction?
13. Lamington	132	0	0	8	45	46	77	
14. Little York	204	0	1	41	34	24	66	
15. Mendham	51	0	0	25	26	49	74	
16. Middle Valley	82	0	0	10	30	60	80	
17. North Branch	81	0	2	15	43	41	75	
18. Oxford, W	304	0	0	57	32	12	62	
19. Oxford, E	234	0	1	45	43	12	64	
20. Pattenburg	165	0	0	8	43	49	78	
21. Peapack	210	0	3	26	41	30	70	
22. Pennwell	56	0	2	21	39	37	72	(Gravelly) till
23. Readington	69	0	3	28	35	35	71	
24. Somerville	100	0	6	17	40	37	72	
25. Tabor	197	0	9	53	36	7	58	Solifluction?
26. Washington	100	0	6	33	45	16	64	
Average Wisconsin	473	10	37	40	10	4	42	

however, how close a number of different people, technical as well as nontechnical, on whom the experiment was tried, have come to the same result. Differences of opinion in this matter lie well within the limits of variation of the drift itself. Furthermore, certain arbitrary standards were set up and carried consistently through the work. If a pebble could be crumbled in the fingers it was in group 5; if it was weathered

through but had to be broken with a blow of the hammer it was in group 4; if it had a thick weathering rind but a fresh core it was in group 3; if it had a thin weathering rind it was in group 2; and if no weathering was visible it was in group 1. Since a comparative rather

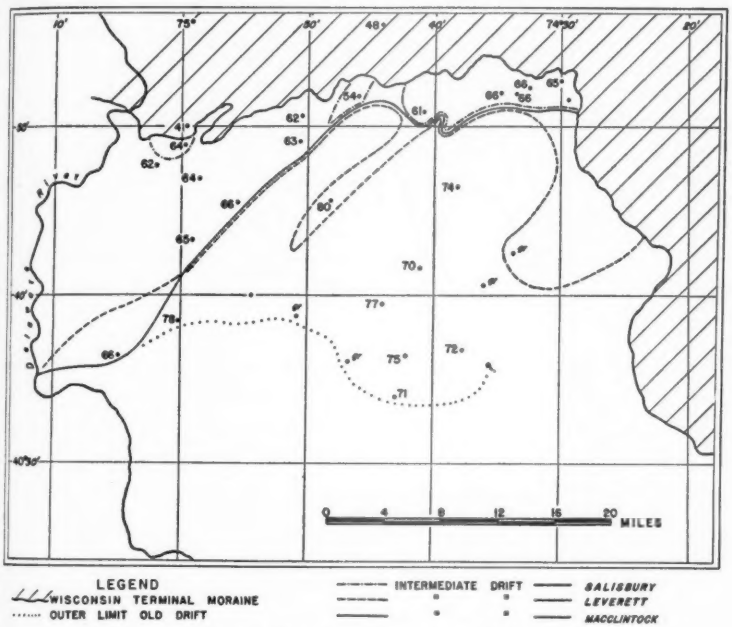

FIGURE 1.—*Part of New Jersey showing the drift boundaries*

Dots designate localities where samples were taken; figures represent mean weathering at these localities; "gr" represents gravel localities.

than an empirical standard is attempted, this classification is considered satisfactory for present purposes. Table 1 summarizes the results of the analyses.

INTERPRETATION OF DATA

An arithmetical mean of the weathering was computed for each station according to the following equation:

$$\frac{10 \times A + 30 \times B + 50 \times C + 70 \times D + 90 \times E}{100} = \text{Mean}$$

where A = % stones in group 1; B = % stones in group 2; C = % stones in group 3; D = % stones in group 4; E = % stones in group 5.

These arithmetic means are plotted on the map (Fig. 1). Also, for a graphical analysis of the date the percentages were plotted as a

curve (Fig. 2). Since we are interested particularly in how much more weathered one patch of till is than another, the two curves were super-

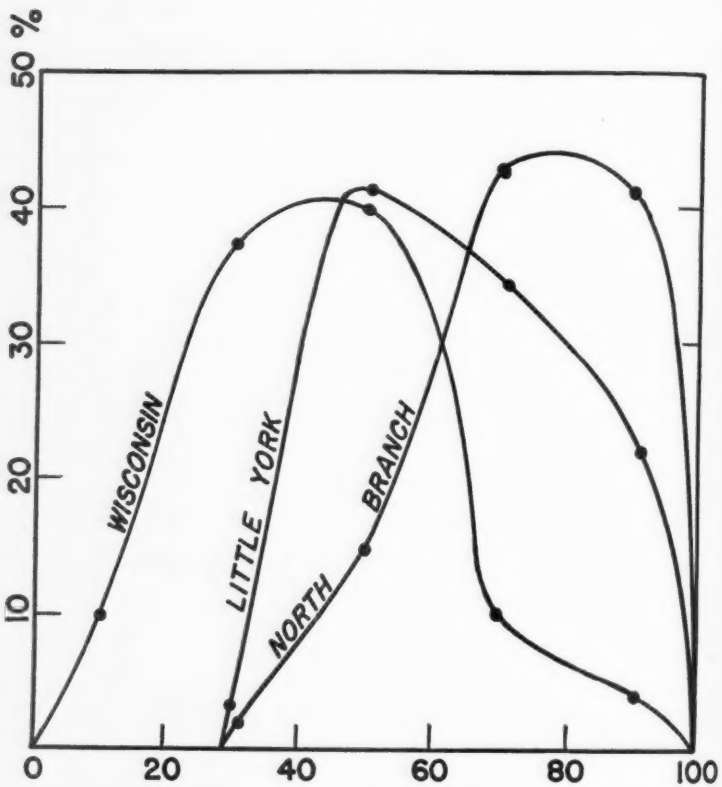

FIGURE 2.—*Graph of the statistical data of the weathering at three typical localities*

Degree of weathering (per cent weathered) is plotted against percentage of stones which are that much weathered in total number of stones in that sample, *i.e.*, per cent in each group.

imposed, by holding the paper up to the light and sliding one along until as good a fit as possible was obtained. This procedure was followed for each of the pebble analyses, and the results agreed almost perfectly with the figure obtained by subtracting the arithmetical mean of one analysis from that of another.

CONCLUSIONS

The mean weathering of the gneissic stones in the Wisconsin drift is 42 percent. This is the average of three analyses: (1) A mile east of Butzville (mean 41); (2) a mile northeast of Oxford (mean 38); and (3) a mile southeast of Cranbury Lake (mean 48). The first two were in calcareous till, the third in leached till.

Till from the area west of Budd Lake has a mean weathering of 54 percent. This is more weathered than the Wisconsin as mapped but much less weathered than the older drifts. It might well be referred to an earlier Wisconsin advance.

South of the Budd Lake drift there appears to be a twofold grouping of the means—one group from 61 to 66 and the other from 70 to 80. While there is more spread within each group than between the groups, the gap between 66 and 70 is larger than any gap among the members of each group. Professor S. S. Wilks, the statistician of the Mathematics Department, Princeton University, established by the "T" test a significant statistical difference between the two groups. His computation gave a figure less than 0.01, which means that there is less than one chance in a hundred that the difference between the two groups is due to causes other than difference in weathering, *i.e.*, age.

It is, therefore, concluded that there are two pre-Wisconsin drift sheets in New Jersey which, as already stated, Salisbury and later Leverett tentatively correlated with the Illinoian and the Kansan.

The average of the means of the Wisconsin drift is 42, that of the intermediate drift 64, and that of the oldest 75. There is, therefore, twice the difference between 42 and 64 than between 64 and 75. It might be inferred therefrom that there had been a greater lapse of time between the deposition of the two younger drift sheets than between the two older ones. This inference, however, is not in accord with the facts as known in the Mississippi Valley region. It seems more reasonable to infer that, in this region where slope wash has played an important role, weathering and wash have gradually brought the profile into a sort of equilibrium. At first weathering might have exceeded wash, and the profile would get older and older. But as it got older and thicker the rate of weathering of new material at its base would become slower. As a result of this slowing down of the rate of weathering it seems probable that slope wash would gradually overtake it and that the two would come into a kind of equilibrium during which there would be no further aging of the profile, even though weathering might be going on for a long time. By this type of reasoning the smaller difference in weathering between the Kansan and Illinoian than between the Illinoian and Wisconsin can be logically explained.

The outermost margin of a drift sheet might well contain, from the start, more weathered material than the drift farther back from the edge because the oncoming ice would have naturally first picked up the weathered material available. Melting at the edge, however, as the glacier advanced, would have liberated the weathered material until it was again picked up by oncoming ice. The ice, though, was now charged with fresh material so that a mixture of fresh and weathered stones would have resulted. It therefore becomes a matter of speculation as to how concentrated the weathered material ever was at the periphery of a drift sheet. No light is shed on this problem by the present study for there seems to be no progressive increase in weathered stones toward the drift border.

The present study, therefore, confirms Salisbury's early interpretation of two pre-Wisconsin drifts, though the boundaries of the intermediate drift are much changed. But it supplies a technique which can be easily understood and applied by even the beginning student and which may have considerable application in Pleistocene studies. It also confirms Leverett's mapping [3] with only three minor changes (Fig. 1). The author has been able to find no important distinction between the gravel at Basking Ridge, near Liberty Corner, near Potterstown, and near White House Station. He would therefore include them all in one drift. The weathering of the till at Middle Valley seems to place it in the older drift, whereas the weathering at Little York would place it with the intermediate drift.

No evidence has come to light during this study to modify Salisbury's and Leverett's correlation with the Illinoian and Kansan. The name Jerseyan, however, as used by Chamberlin and by Salisbury, becomes a group name equivalent to "pre-Wisconsin."

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[3] Leverett very generously sent the author a manuscript map of the drifts of New Jersey, which he had prepared for the Pennsylvania report but which was not published in that report, and has given permission to utilize it in this present paper.

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NEOCOMIAN FAUNAS OF NORTHERN MEXICO

BY RALPH W. IMLAY

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ABSTRACT

Thick, clastic deposits of Neocomian age mark the margin of the former Coahuila Peninsula of northern Mexico. They contain a large fauna, consisting mainly of mollusks and brachiopods, the study of which has made possible correlations of the various facies of the Mexican geosyncline. The faunal assemblage is remarkably similar to that in the Neocomian deposits of France, England, and Switzerland, and belongs decidedly in the Mediterranean province. No species in common are known between the Neocomian deposits of Mexico and the Upper Jurassic Malone formation of Texas.

INTRODUCTION

Near-shore facies of Neocomian age have been noted in southern Mexico (Felix, 1891, p. 180-194; Burckhardt, 1930, p. 159-162; Sapper, 1937, p. 44), along the Sierra Madre Oriental (Böse and Cavins, 1927, p. 17-18, 56-58; Burckhardt, 1930, p. 142-144, 154-157; Imlay, 1937a, p. 552-574), around the margin of the Coahuila Peninsula in eastern Durango and eastern Coahuila (Kellum, 1936, p. 1053, 1057-1059, 1067-1070; Burckhardt, 1930, p. 144-147), and near Torcer, Texas (Albritton, 1938, p. 1764-1767). Similar facies of Neocomian age must have been formed along the western margin of the Mexican geosyncline but have not yet been discovered. The ages of the sections in eastern Durango have been discussed by the writer (1938b, p. 1684, 1687). The sections in eastern Coahuila have been studied in considerable detail by Wm. G. Kane and will be described by him in a forthcoming paper. The present paper deals mainly with the Neocomian faunas that inhabited the shallow seas bordering the Coahuila Peninsula, suggests correlations with previously described Neocomian deposits of other parts of Mexico, confirms the previous correlations based on ammonites in offshore facies (Imlay, 1938a, p. 550-552), and shows that the Neocomian deposits of Mexico contain an entirely distinct mollusk assemblage from the Malone formation of western Texas. Included are descriptions of a few new and especially interesting ammonites from the offshore Taraises formation of southern Coahuila (Pl. 21).

ACKNOWLEDGMENTS

The fossils described herein were obtained mainly by Lewis B. Kellum, Wm. G. Kane, T. S. Jones, and R. W. Imlay in the course of structural and stratigraphic studies in northern Mexico. All the collections from eastern Durango, southern Coahuila, and some from eastern Coahuila were made possible by financial support from The Geological Society of America. Most of the fossils from eastern Coahuila were obtained by Wm. G. Kane while in the employ of the Ohio-Mexican Oil Company and were subsequently donated to the Museum of Paleontology

FIGURE 1.—*Neocomian paleogeography of Mexico*

TABLE 1.—*Correlation of Mesozoic deposits near Coahuila Peninsula of northern Mexico*

European equivalents		Texas equivalents	Laguna district (modified after L. B. Kellum)	Unit	Sierra de Parras and Parras Basin (R. W. Imlay)	Barril viejo (After Wm. G. Kane)	Potrero de Menchaca (Wm. G. Kane)
Upper Cretaceous	Senonian	Maestrichtian	Navarro				
		Campanian			Difunta formation		
		Santonian	Taylor		?		
		Coniacian	Austin		Parras shale		
	Turonian	Eagle Ford	Indidura formation		Caracol formation	?	
	Cenomanian	Woodbine			Indidura formation		
		Washita				Present	
Lower Cretaceous	Albian	Fredericksburg	Aurora limestone		Cuesta del Cura		
					Aurora limestone	Aurora limestone	Aurora limestone
	Aptian	Trinity	La Peña formation		La Peña formation	Present	Cuchillo formation
		?				?	?
	Neocomian	Barremian		1	Parritas formation	Patula arkose	La Mula formation
			Parritas formation		Cupido limestone		
		Hauterivian	Las Vigas formation	2	Las Vigas	Padilla limestone	Padilla limestone
		?					
		Valanginian	Taraises formation	3		Barril viejo shales	Barril viejo shales
				4	Taraises formation		
		Torcer formation		A		San Marcos arkose	San Marcos arkose
					?		
		Berriasian	Carbonera formation	B			Menchaca limestone
		?	?		Haitus		Unnamed shales
Jurassic	Tithonian	Haitus	La Casita formation	C	?		
	Portlandian	Malone formation			La Casita formation		
	Kimmeridgian	?	?				
	Oxfordian		La Gloria formation	D E	La Gloria formation		

of the University of Michigan. The writer is greatly indebted to Mr. Kane for preparing generalized descriptions of the sections in Barril viejo and Potrero de Menchaca. All new formation names mentioned in these sections were proposed by him. This paper completes the study of the Neocomian faunas in the University of Michigan collections.

STRATIGRAPHY

EASTERN COAHUILA

Lower Cretaceous rocks approximating 9000 feet in thickness are well exposed in the deeply eroded anticlinal uplifts of east-central Coahuila (Fig. 2). The Neocomian is represented by arkoses, shales, limestones, and minor amounts of gypsum; the Aptian by arkoses, shales, marls, dolomites, dolomitic limestone, and considerable gypsum; and the Albian in part by several thousand feet of thick-bedded limestone which forms escarpments and mountain crests. The Neocomian sediments become finer and more calcareous eastward, that is, away from the Coahuila Peninsula. Dolomites and gypsum of Aptian age occur in areas on, or near, the site of the Coahuila Peninsula. The limestones of the Albian appear to be somewhat thicker in areas around the margin than on the peninsula.

The generalized section in Barril viejo, measured by Wm. G. Kane, from top to bottom, is as follows:

	Feet
1. Aurora limestone (in part) Thick-bedded, gray limestone. Basal marly beds contain *Dufrenoya texana* Burckhardt	3500
2. Patula arkose (Type locality Potrero de Patula) Green and brown graywackes and arkoses	1500
3. Padilla limestone (Type locality Potrero de Padilla) Dark blue, thick-bedded limestone, containing some arkosic impurities near base	50
4. Barril viejo shale (Type section) Dark blue-gray, calcareous shale containing many fossils of middle Neocomian age	100
5. San Marcos arkose (Type locality Cañón de San Marcos) Red, coarse, granitic arkose, contains red-stained, white granite boulders ranging up to 30 inches in diameter	700
Total	5850±

The generalized section in the Potrero de Menchaca, measured by Wm. G. Kane, from top to bottom, is as follows:

	Feet
1. Aurora limestone (in part) Thick-bedded, gray limestone (not measured) probably	3500?
2. Cuchillo formation Bedded gypsum with intercalations of limestone and shale. Distinctive beds of compact, honey-combed yellow limestone. Several compact, gray limestone units similar to overlying Aurora limestone. Lowest member is a very resistant yellow-gray limestone	1099

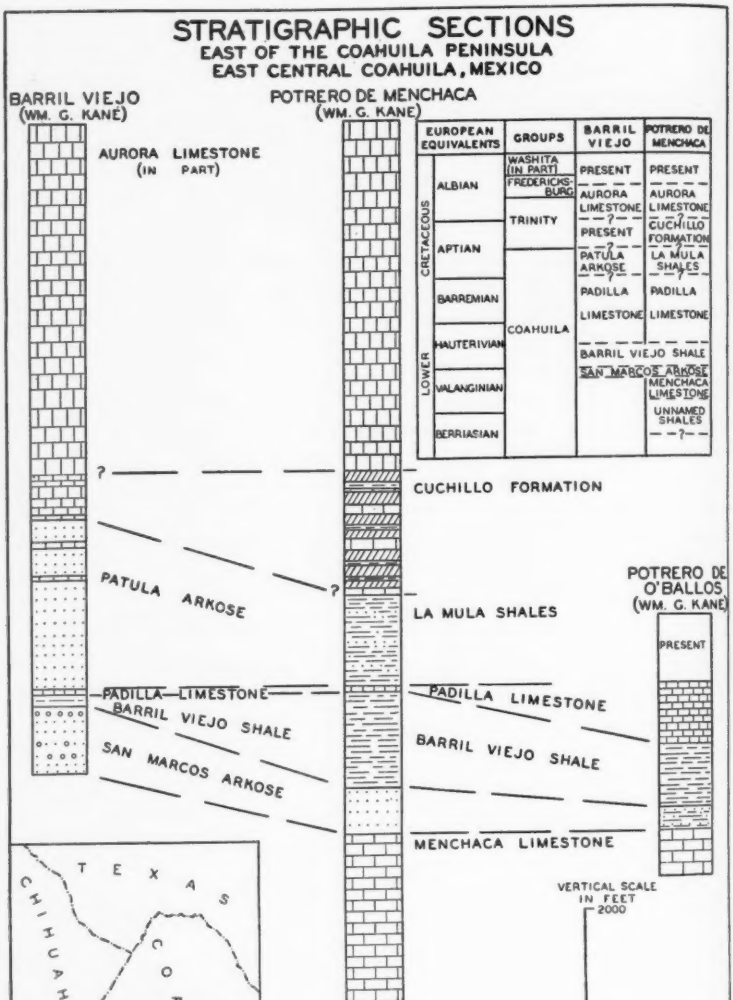

FIGURE 2.—*Stratigraphic sections in eastern Coahuila*

	Feet
3. La Mula shales (Type locality Potrero de la Mula) Gray, green, pink, purple, and yellow shales and sandy shales. Easily eroded and forming valley topography	794
4. Padilla limestone Thick-bedded, dark-blue-gray limestone. Contains large gastropods	50?
5. Barril viejo shale Dark blue, calcareous shale containing many fossils of middle Neocomian age	843
6. San Marcos arkose Granitic arkose similar to that in the Barril viejo section but without granitic boulders and considerably finer-grained. Coarser-grained than equivalent arkosic beds at Padilla. Intercalations of limestone and dolomite as tongues feathering out toward the south and thickening toward the north. Upper and lower edges of calcareous units have arkosic impurities. Contains no volcanic material	410
7. Menchaca limestone (Type section) Dark blue-black limestone in beds averaging 18 inches in thickness. Lower part contains white calcite replaced *Exogyras*, namely, *E. reedi* Imlay and *E. putnami* Imlay	1743
8. Unnamed shales Brown and gray shales and sandy shales with intercalated beds of brownish-gray, even-bedded limestone ranging up to several feet in thickness. Weather brownish-yellow. A marly bed at base contains *Exogyra reedi* Imlay, *E. putnami* Imlay, and *Vermetus cornejoi* Castillo and Aguilera	557
Total	8996±

Sections in the Sierras de Azul and Oballos have been measured by Müllerried (Burckhardt, 1930, p. 143-144). These sections, as well as others, have been studied by Wm. G. Kane and will be described by him. The formations are in general similar to those at Barril viejo and Menchaca but somewhat more calcareous. At Potrero de Oballos there are about 547 feet of Padilla limestone, 554 feet of Barril viejo shale, 204 feet of underlying shales and fine-grained sandy rocks, and 412 feet of Menchaca limestone.

EASTERN DURANGO

The Neocomian deposits of eastern Durango comprise about 2000 feet of arkose, sandstone, shale, and limestone (Kellum, 1936, p. 1053, 1057-1059, 1067-1070; Imlay, 1938b, p. 1687). They show considerable variation in lithology laterally and vertically but in general constitute well-defined formations similar to the Neocomian formations of southern Coahuila (Imlay, 1936, p. 1111-1119). Near their base occurs a highly fossiliferous zone characterized by *Exogyra reedi* Imlay and gigantic forms of *Thurmannites*. The sections will be briefly summarized below.

The section on the west side of the Sierra de Mapimí about half a mile south of Puerto Soldados, from top to bottom, may be summarized as follows:

	Feet
1. Parritas formation Unit 1 in part. Siliceous limestone, yellow to yellowish-gray, or less commonly pink. Beds from 1 to 5 feet thick. Some intercalated lenses of yellow, gray, or red sandstone and gray, yellow, or green shale	248

	Feet
2. Las Vigas formation	
Unit 2. Sandstone, red, fine-grained, with interbedded reddish gray arkose and red or green sandy shale	112
3. Taraises formation	
Unit 3. Limestone, light-gray, thin-bedded, weathering buff. Siliceous in lower half. A few beds of yellow quartz sandstone	335
Unit 4. Arkose, gray to reddish, interbedded with buff, gray, and green limestone which is siliceous at top and marly at the base. Some shale partings and quartz sandstone lenses. Arkose locally conglomeratic	325
4. Carbonera formation	
Unit 5. Gray, quartz sandstone alternating with layers of shale and shaly sandstone. Coarse, greenish-gray arkose in basal part. Collection 34 obtained from lowest sandstone escarpment about 1000 feet below top. Formation includes the Cretaceous beds below the Taraises formation. Type locality is the Cuesta del Carbonera about 2 miles south of Las Cuevas, Durango	1300
Total	2320

The section across the Cuesta del Carbonera about 2 miles south of Las Cuevas ranch, from top to bottom, may be summarized as follows:

	Feet
1. Taraises formation (lower member)	
Unit A. Upper part of measured section consists of gray and yellow, calcareous sandstones and shaly sandstones. Lower 180 feet consists of gray, siliceous limestone. At least	325
2. Carbonera formation (Type section)	
Unit B. Consists of interbedded gray sandy shale and shaly sandstone, which weathers buff. Collections A-4 and A-3 made about 340 and 363 feet respectively from top	738
Total	1063

The upper part of unit A above the part measured by Kellum (1936, p. 1053) consists of gray, siliceous limestone, according to observations made by the writer. It is overlain in Cañón de los Cabritos, immediately east of Cuesta del Carbonera, by light-gray, thin-bedded limestones lithologically like the upper member of the Taraises formation (Imlay, 1936, p. 1111). Directly above, on the east side of the canyon, occurs several hundred feet of sandstone and shale of Las Vigas formation which is overlain by yellowish limestones identified with the Parritas formation.

"COAHUILA GROUP," A NEW STRATIGRAPHIC TERM

During the course of studies in Mexico the writer has felt the need of a group term to designate Lower Cretaceous strata older than Trinity as that term is generally understood in Texas (Hill, 1901). Discussions with W. S. Adkins and John B. Reeside, Jr., have led to agreement as to the definition and usefulness of such a term. The Trinity becomes much too comprehensive for usefulness if extended to include all Lower Cretaceous rocks older than Fredericksburg as proposed by Adkins (1932,

p. 284-286). Consequently the writer herein proposes the "Coahuila group" to include all Lower Cretaceous strata older than the *Dufrenoya texana* zone which were deposited in the ancestral Gulf of Mexico, in the Mexican sea, and in closely connected waters.

John B. Reeside (personal communication, September 28, 1939) and other members of the United States Geological Survey have

> "agreed that the single use of 'Coahuila' by Dallas Hanna for Pleistocene silts in the Imperial Valley, California, is not sufficient to bar its use as a group term to apply to Lower Cretaceous rocks in Coahuila, Mexico, and other areas."

The Coahuila group is named after the Mexican State of Coahuila, wherein it is fully developed in both near-shore and off-shore facies which have been described in various publications by Burckhardt (1930), Böse (1923, 1927), Kellum (1936), and Imlay (1936, 1937a, 1937b, 1938a and 1938b). The head of Cañón Taraises in the western part of the Sierra de Parras (Imlay, 1936, p. 1111-1124, pl. 8, fig. 1; pl. 10) may be designated as a typical locality. Other localities in which the group is well exposed are La Casita Uplift in the middle part of the Sierra de Parras (Imlay, 1937b, p. 605-607), Valle Menchaca in eastern Coahuila (described herein), the Sierra de Mapimí in eastern Durango (Kellum, 1936, p. 1067-1071), and the valley south of Cañón de Santa Catarina near Monterrey, Nuevo León (Böse and Cavins, 1927, p. 17-18).

The Coahuila group crops out extensively in Mexico (Fig. 1), in small areas in southwestern Texas, and, as revealed by well drilling, undoubtedly underlies Louisiana, southern Arkansas, and eastern Texas. Compared with the younger groups of the Lower Cretaceous, it represents a time of rather restricted marine overlap on the continent. Its relations to these younger groups and to the European standard section are shown in Table 2.

PALEOGEOGRAPHIC RELATIONSHIPS

During the Upper Jurassic and Neocomian the Coahuila Peninsula projected southward from the main North American landmass as a persistent positive area which passed beneath the Mexican sea in southern Coahuila. At the beginning of the Neocomian the peninsula extended as far south as the Sierra de Parras in southern Coahuila and was probably somewhat broader than indicated on the paleogeographic map (Fig. 1). It was transgressed by the Mexican sea early in the Neocomian and eventually submerged in upper Aptian time. During the Neocomian the bordering sea bottoms received several thousand feet of sediments which, near shore, consisted mainly of arkoses and shales but which graded seaward into marls and limestones of lesser thickness. The

character and thickness of the lithologic units formed near-shore vary considerably from place to place, probably depending on the position of the rivers which drained the land or perhaps on local uplift, but the offshore units, comprising the Taraises formation, are remarkably simi-

TABLE 2.—*Relations of Coahuila group*

European equivalents			Gulf region and Mexican groups	Characteristic ammonites
Lower Cretaceous		Albian	Washita (in part)	*See* Adkins, (1932, p. 318, 327, 363)
			Fredericksburg	
		Aptian	Trinity	*Dufrenoya texana*
	Neocomian	Barremian	Coahuila	Ancyloceratidae
				Pseudohaploceras Pulchellia
		Hauterivian		*Olcostephanus raricostatus, Maderia, Mexicanoceras, Leopoldia, Acanthodiscus* aff. *radiatus*
		Valanginian		*Rogersites, Valanginites, Dichotomites*
				Thurmannites miquihuanaensis and related species
		Berriasian		*Berriasella, Subthurmannia,* and *Spiticeras*

lar over large areas. In general the deposition of coarse clastic sediments decreased in amount during the Neocomian and occurred mainly during the Berriasian, lower Valanginian, and Hauterivian stages. Limestone deposition near shore occurred during the upper Valanginian and Barremian stages. Burckhardt (1930, p. 164) considered that the arkosic deposits of Hauterivian age, comprising Las Vigas formation and its equivalents, marked a regressive phase. The writer considers it more likely that the main uplift of Coahuila Peninsula occurred at the end of Jurassic time and that the Hauterivian arkoses mark the beginning of a period of aridity which culminated in the Aptian.

FOSSILS

LOCALITIES

Eastern Coahuila.—Most of the fossils were obtained from the Barril viejo shale at Barril viejo, Potrero de Oballos, Potrero de Menchaca, and

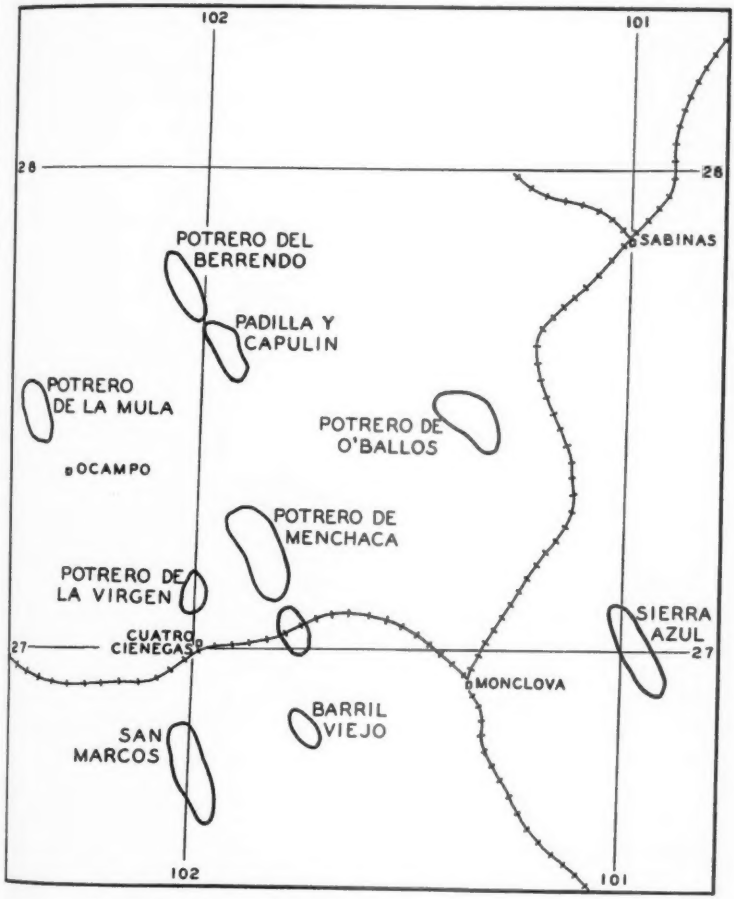

FIGURE 3.—*Index map of fossil localities in eastern Coahuila*

the Sierra de Azul (Fig. 3). At Potrero de Menchaca Exogyras occur in abundance in the Menchaca limestone and in the lowest beds of the section. The collecting localities at Barril viejo and Potrero de Menchaca are indicated on Figures 4 and 5.

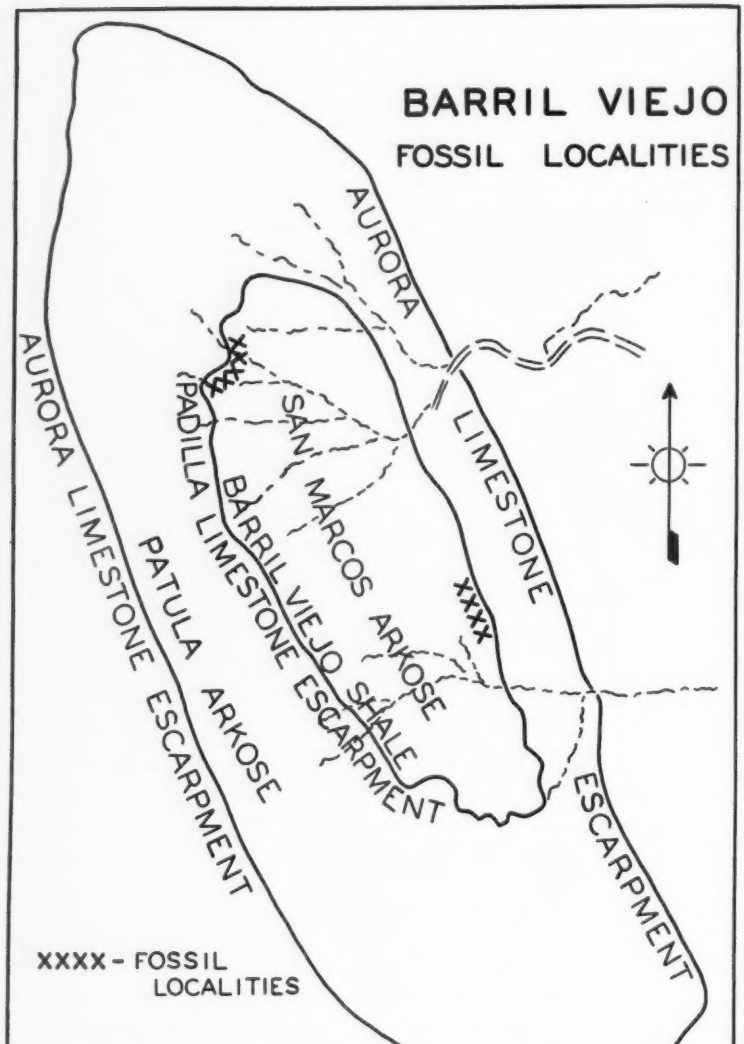

FIGURE 4.—*Index map of fossil localities at Barril viejo, Coahuila*

Eastern Durango.—The positions of the fossil localities in eastern Durango are indicated on a map by Kellum (1936, pl. 14) and will be briefly described. All collections were made from the Carbonera formation.

LOCALITY A-4: Cuesta del Carbonera about 2 miles south of Las Cuevas ranch. Collection obtained from shales about 400 feet above the base of unit B. Another collection was made by the writer at the northwest end of the cuesta at the same horizon as A-4.

LOCALITY A-34: West side of the Sierra de Mapimí, about half a mile south of the western end of Puerto de Soldados. Collection obtained about 1000 feet below the top of unit 5 just above the lowest sandstone escarpment on the left side of the largest canyon.

LOCALITIES K-96, 97, 98: Northwest end of Sierra de Hispaña, about a mile northeast of La Goma station. Collections K-96, 97, and 98 were made 18, 38, and 60 feet respectively above the base of the exposed section of sandy shale.

LOCALITY A-37: Puerto de Soldados, north of trail, about half a mile west of Cañón Colorado.

Southern Coahuila.—The positions of the fossil localities in the Sierra de Parras are indicated in published papers (Imlay, 1937b, fig. 3; 1938a, p. 546, 547). Fossils described herein were obtained from the Taraises formation at localities 18, 20, 42, and 58, and from the contact beds of the Cupido limestone-La Peña formation at locality 32.

BIOLOGICAL ANALYSIS

The faunal assemblage of the near-shore deposits consists dominantly of thick-shelled gastropods, pelecypods, and brachiopods. Corals, echinoids, and ammonites are comparatively rare. New species include 1 coral, 4 brachiopods, 16 pelecypods, 4 gastropods, and 2 ammonites. These species as well as others discussed herein are listed in Table 5. Nearly one-third of the recognizable species are too poorly preserved to merit description.

The corals are represented by *Astrocoenia hispaniensis* Imlay, n. sp., and by several imperfect specimens which probably belong to *Montlivaultia*, *Pleurosmilia*, and *Coelosmilia*. Most of the echinoids are crushed or fragmentary. The best preserved corals and echinoids were obtained from the Barril viejo shale of eastern Coahuila. The brachiopods are abundant and well preserved. They comprise five species distributed among three genera. The generic determinations should be considered tentative.

The pelecypods are represented by 15 families, 22 genera, and numerous species of which about half are described. The genera *Pinna*,

Ostrea, Alectryonia, Trigonia, Pecten, Camptonectes, Spondylus, and *Cyprina* are represented by a few fragmentary specimens. The distribution of families, genera, and species is shown in Table 3.

The gastropods are represented by seven genera and eleven species

TABLE 3.—*Biological distribution of Neocomian pelecypods from northern Mexico*

Family and Genus	Total number of species	Number of species described	Family and Genus	Total number of species	Number of species described
Parallelodontidae			Limidae		
Cucullaea	3	2	*Lima* (*Plagiostoma*)	1	1
Grammatodon	2	0	Gervillidae		
Pinnidae			*Gervillia*	1	1
Pinna	2	0	Astartidae		
Ostreidae			*Astarte*	1	1
Ostrea	1	0	Cyprinidae		
Alectryonia	1	0	*Cyprina*	1	1
Gryphaea	2	2	Pleurophoridae		
Exogyra	2	2	*Trapezium*	2	2
Trigonidae			Lucinidae		
Trigonia	4	0	*Lucina*	1	1
Pectinidae			Corbidae		
Pecten	1	0	*Sphaera*	1	1
Syncyclonema	2	0	Saxicavidae		
Camptonectes	2	0	*Panope*	1	1
Neithea	2	1	Pholadomyidae		
Prohinnites	1	1	*Pholadomya*	2	1
Spondylidae				44	23
Plicatula	6	4			
Spondylus	2	1			

of which six are discussed and illustrated. The genera include *Harpagodes, Nerinea, Vermetus, Natica?, Trochus, Turbo,* and *Pleurotomaria. Harpagodes* is especially interesting because of its giant size and similarity to forms in France. *Turbo? coahuilensis* Imlay, n. sp., probably belongs to an undescribed genus.

The ammonites found in the near-shore deposits are mainly thick-shelled members of the Neocomitidae, including *Thurmannites, Leopoldia,* and *Acanthodiscus.* One large form of *Dichotomites* is the sole representative of the Oleostephanidae.

Many of the ammonites found in the offshore Neocomian deposits have been described previously (Imlay, 1938a), but herein are added ten

species distributed among seven genera, as shown in Table 6. Of particular interest is the occurrence of *Oosterella?* in beds of lower Hauterivian age and of *Saynoceras* in beds of probable upper Barremian age.

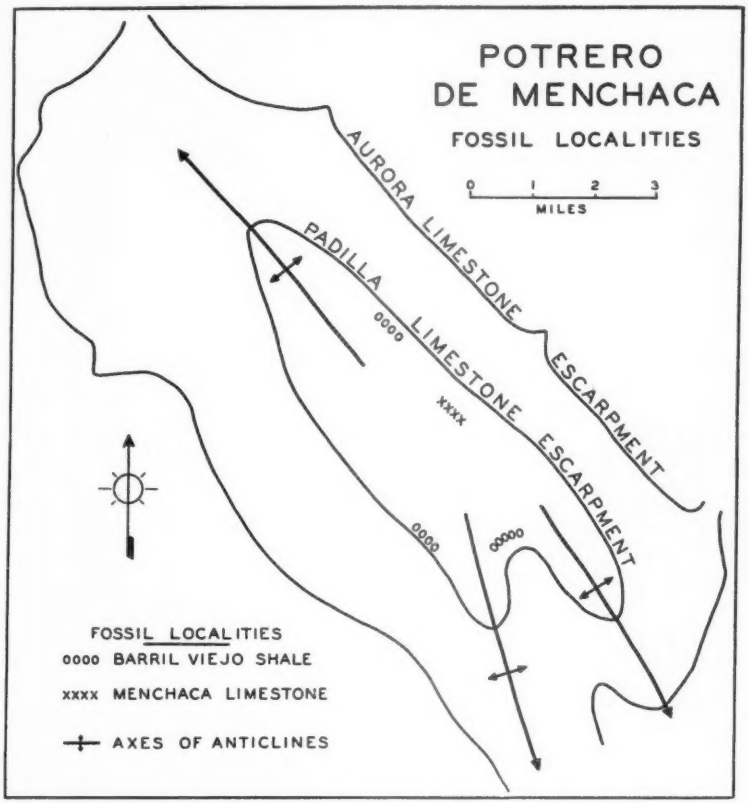

FIGURE 5.—*Index map of fossil localities at Potrero de Menchaca, Coahuila*

Hemihoplites? mexicanus Imlay, n. sp., probably represents an undescribed genus of the Hemihoplitidae. Descriptions of two new species of *Mexicanoceras* and three new species of *Maderia* contribute to the knowledge of these genera (Imlay, 1938a, p. 557-568).

CORRELATION

In eastern Coahuila the key formations of the Lower Cretaceous are (1) The marly beds with *Dufrenoya texana* Burckhardt at the base of

TABLE 4.—*Similar Neocomian species in Mexico and Europe*

Mexican species	Similar European species	Range of European species
"Terebratula" coahuilensis Imlay	*"T" carteroniana* d'Orbigny	Middle Neocomian
Cucullaea gabrielis var. *fraterna* Imlay	*C. gabrielis* Leymerie	Valanginian to Aptian
Plicatula pulchra Imlay	*P. strambergensis* Boehm	Tithonian to Hauterivian
Neithea cf. *atava* (d'Orbigny)	*N. atava* (d'Orbigny)	Neocomian to Lower Aptian
Prohinnites ordoñezi Imlay	*P. leymerii* Deshayes	Valanginian to Aptian
Exogyra reedi Imlay	*E. latissima* var. *couloni* (Defrance)	Neocomian
Trigonia cf. *carinata* Agassiz	*T. carinata* Agassiz	Lower Cretaceous
Gervillia alatior Imlay	*G. alaeformis* (Sowerby)	Neocomian and Lower Aptian
Cyprina cf. *bernensis* Leymerie	*C. bernensis* Leymerie	Middle Neocomian
Lucina kellumi Imlay	*L. dupiniana* d'Orbigny	Hauterivian
Sphaera americanus Imlay	*S. corrugata* Sowerby	Neocomian to Lower Aptian
Panope cf. *gurgitis* (Brongniart)	*P. gurgitis* (Brongniart)	Neocomian to Lower Albian
Pholadomya cf. *sanctae-crucis* Pictet and Campiche	*P. sanctae-crucis* Pictet and Campiche	Valanginian
" cf. *gigantea* (Sowerby)	*P. gigantea* (Sowerby)	Valanginian to Aptian
Turbo n. sp. aff. *mantelli* Leymerie	*T. mantelli* Leymerie	Neocomian
Natica cf. *hugardiana* d'Orbigny	*N. hugardiana* d'Orbigny	Middle Neocomian
" cf. *neptuni* d'Orbigny	*N. neptuni* d'Orbigny	Lower to middle Neocomian
Tylostoma cf. *laharpi* Pictet and Campiche	*T. laharpi* Pictet and Campiche	Valanginian
Harpagodes mexicanus Imlay	*H. jaccardi* Pictet and Campiche	Valanginian
" *americanus* Imlay	*H. desori* Pictet and Campiche	Valanginian
Dichotomites multicostatus Imlay	*D. terscissus* (von. Koenen)	Upper Valanginian
Acanthodiscus aff. *radiatus* Bruguière	*A. radiatus* Bruguière	Lower Hauterivian
Leopoldia crassicostata Imlay	*L. dubisiensis* var. *bargemensis* Kilian	Hauterivian

the Aurora limestone and (2) the Barril viejo shale with *Acanthodiscus* and *Leopoldia*. The former represents the upper Aptian, and the latter the lower Hauterivian of the European stages. The Barril viejo shale is correlated directly with the upper member of the Taraises formation of the central part of the Mexican geosyncline on the basis of the occurrence of *Acanthodiscus magnificus* Imlay, *A.* cf. *radiatus* Bruguière, *Leopoldia victoriensis* Imlay, and *L.* cf. *bakeri* Imlay. Numerous ammonites obtained from the upper member of the Taraises formation show that its age is lower Hauterivian (Imlay, 1938a, p. 551-552). Further age evidence is furnished by the remarkable similarities of the gastropods, pelecypods, and brachiopods of the Barril viejo shale to species occurring in the middle Neocomian beds of France, Switzerland, and England. The most striking faunal similarities with the European Neocomian are shown in Table 4.

As the Barril viejo shale of eastern Coahuila is the near-shore equivalent of the upper member of the Taraises formation, a tentative correlation may be made of the adjoining formations (Table 1). The Padilla limestone, overlying the Barril viejo shale, is probably equivalent to the Cupido limestone. The Patula arkose, the Cuchillo formation in part, and the marly beds at the base of the Aurora limestone in eastern Coahuila are correlated with La Peña formation. The Menchaca limestone and the underlying unnamed basal shales at Potrero de Menchaca contain *Exogyra reedi* Imlay and *E. putnami* Imlay which are common in the basal Cretaceous beds near Miquihuana, Tamaulipas. These formations are, therefore, of lower Neocomian age and are correlated with the lower member of the Taraises formation.

In most of the mountainous uplifts of east-central Coahuila the oldest outcropping beds are Lower Cretaceous. Jurassic strata have been reported by Burckhardt (1930, p. 83, 84, 143) in the (1) Valle de San Marcos and (2) in the Sierra de Azul, and by Burckhardt and Müllerried (1936, p. 313, 314) from (3) a well boring near Camarón, Nuevo León, at a depth of about 8700 feet.

In eastern Durango the key formations are La Peña with *Dufrenoya texana* Burckhardt and the Carbonera with *Thurmannites* and *Exogyra reedi* Imlay. Correlations of the beds between La Peña and Carbonera formations have already been discussed elsewhere (Imlay, 1938b, p. 1687-1688). Collections A-4 and A-34 from the middle part of the Carbonera formation contain species of *Thurmannites* like *T. novihispanicus* Imlay and *T. miquihuanensis* Imlay from Miquihuana, Tamaulipas (Imlay, 1937a, p. 563-564). These resemblances indicate an early Neocomian age. Several fragments probably represent *Blan-*

fordiceras and *Berriasella* which suggest an age slightly older than the upper Valanginian.

Formerly the writer suggested (1938b, p. 1684-1685) that the Jurassic-Cretaceous boundary probably occurs in the middle of unit B of the Cuesta del Carbonera section. Reconsideration of the evidence, however, favors the location of the boundary at the base of unit B (and 5) (Kellum, 1936, p. 1067). The only ammonites which might have come from the lower part of unit B are generically undeterminable, and their stratigraphic positions are highly uncertain (Imlay, 1938b, p. 1685). One is probably a *Spiticeras*, and the other, referred formerly to *Kossmatia*, is probably a distorted *Thurmannites*. Kellum does not record any fossils below the horizon of Collection A-34 in unit 5 of the Sierra de Mapimí section. From a small knoll near Kilometer 719 on the Mazatlan highway, Kellum (1936, p. 1068) obtained Collection A-33 which contains pelecypods characteristic of the Malone fauna of west Texas. The collection was made several hundred feet lower stratigraphically than A-34 and might represent either the top of unit C or the base of unit 5. The matrix around the fossils is like that of other collections from unit C. In the absence of diagnostic fossils from the lower part of units 5 and B, it is preferable to consider the base of these units as the Jurassic-Cretaceous boundary.

All the Neocomian stages are represented in Mexico by described faunas. The Berriasian is represented by rich faunas from Cerro de la Virgin near Tlaxico, Oaxaca (Felix, 1891, p. 180-194), and from San Pedro del Gallo, Durango (Burckhardt, 1912, p. 172-195, 227-229). It is characterized by numerous species of *Spiticeras*, *Berriasella*, and *Subthurmannia* Spath (1939, p. 48). *Himalayites* has been recorded (Burckhardt, 1930, p. 93, 95) but is not common. The Valanginian is known by faunas from the Miquihuana region of Tamaulipas and Nuevo León (Imlay, 1937a) and from eastern Durango. The beds with *Rogersites* and *Valanginites* near San Lazaro, Nuevo León, are probably of upper Valanginian age. The writer suspects that careful collecting would show that the beds characterized by *Thurmannites miquihuanensis* Imlay and related giant forms occur somewhat lower stratigraphically than the beds characterized by *Rogersites* and represent the middle Valanginian. This is indicated by the collections from the section on the west flank of the San Lazaro anticline (Imlay, 1937a, p. 555, 558) where *Rogersites*, *Valanginites*, and *Distoloceras* were obtained from higher beds than the giant *Thurmannites*. A similar stratigraphic arrangement has been determined by Spath (1939, p. 128) for the cephalopods from the Salt Range of India. The lower part of the Cretaceous section in eastern Durango likewise contains gigantic *Thurmannites* similar to those near

Miquihuana and is probably about the same age. Curiously, these Mexican forms of *Thurmannites* bear strong resemblances to the Berriasian-Tithonian group of *Berriasella chaperi* (Pictet) and *B. malbosi* (Pictet) (Mazenot, 1939, p. 80-102). These resemblances suggest to the writer that the Lower Cretaceous sections in the Miquihuana region should be restudied carefully. The lower Hauterivian is represented by an abundant fauna in both offshore and nearshore deposits. Most of the described species have been obtained from southern and eastern Coahuila (Imlay, 1938a) and southeastern Durango (Böse, 1923, p. 69-102), but some have been recorded from San Pedro del Gallo, Durango (Burckhardt, 1912, p. 196-197), and from the Mazapil region of Zacatecas (Burckhardt, 1906, p. 183-191). The lower Hauterivian is characterized by an abundance of the ammonites *Olcostephanus, Maderia, Mexicanoceras, Acanthodiscus* (*s.s.*), *Leopoldia, Neocomites,* and *Distoloceras. Thurmannites, Valanginites, Kilianella,* and *Dichotomites* are known but are more characteristic of the Valanginian. The upper Hauterivian and Barremian are poorly represented by fossils. Böse (1923, p. 102-118) has described a few Barremian species of *Pulchellia* and *Pseudohaploceras* from the Sierra de Symón in southeastern Durango. Felix (1891, p. 142-172) has described a reef fauna of Hauterivian or Barremian age from San Antonio de Las Salinas, Puebla (Burckhardt, 1930, p. 158-160). Müllerried (1936, p. 36) obtained a near-shore Neocomian fauna, apparently similar to that in the Barril viejo shale of Coahuila, from the upper part of the Todos Santos series of northern Chiapas. According to Sapper (1937, p. 44) the Metapan beds of middle Honduras and northwest Salvador contain a near-shore fauna which is predominantly Neocomian.

A small collection of ammonites of probable upper Barremian age was obtained at locality 32 in the Sierra de Parras, Coahuila (Imlay, 1937b, p. 610). It contains *Saynoceras mexicanum* Imlay, n. sp. (Pl. 21, figs. 1-4) and some small fragments definitely belonging to the Ancyloceratidae. Both *Parancyloceras* and *Ancyloceras* are probably represented. These might indicate either a Barremian or lower Aptian age but, as the fossils were obtained about a thousand feet below the top of La Peña formation, they most likely represent a horizon as old as upper Barremian.

Concerning the controversy about the age of the pelecypods of the Malone formation of Texas (*see* summaries in Adkins, 1932, p. 256, 290, 291; Albritton, 1938, p. 1749-1751), the writer can state that the known Neocomian faunas of Mexico are definitely distinct from the Malone fauna, whereas the Upper Jurassic faunas of Mexico contain many species which are identical with species in the Malone fauna. In the Neocomian beds of eastern Durango occur a few poorly preserved speci-

mens of *Pinna* and *Pecten* which have been compared with some of the Malone species but are not specifically identical. Forms identified by Kellum (1936, p. 1068) with *Vermetus cornejoi* Castillo and Aguilera, *Rhynchonella lacunosa* Castillo and Aguilera, and *Cucullaea catorcensis* Castillo and Aguilera from the Upper Jurassic beds near Catorce, San Luis Potosí, are described in this report as new forms under the names *Vermetus cornejoi* var. *varians* Imlay, *"Rhynchonella" durangensis* Imlay, and *Cucullaea striatiumbonata* Imlay. They do not indicate a correlation with the beds near Catorce.

TABLE 5.—*Distribution of submarginal Neocomian fossils*

Species	Eastern Coahuila						Eastern Durango						
				Potrero de Menchaca			Cuesta del Carbonera						
	Barril viejo	Sierra de Azul	Potrero de Oballos	Barril viejo shale	Menchaca limestone	Unnamed shale	Loc. A-3	Loc. A-4	N. W. end	Loc. 34	Loc. 37	Locs. 96 and 97	Loc. 98
Astrocoenia hispaniensis Imlay									x				
"Terebratula" coahuilensis Imlay	x	x	x										
T. kanei Imlay		x	x										
Antiptychina? formosa Imlay		x											
A. ? aff. müllerriedi Imlay								x					
"Rhynchonella" durangensis Imlay								x					
Cucullaea striatiumbonata Imlay										x			
C. aff. striatiumbonata Imlay													x
C. gabrielis var. *fraterna* Imlay	x												
C. sp.										x			
Grammatodon sp.	x												
Pinna cf. *quadrifrons* Cragin										x			
Pinna sp.	x								x				
Exogyra reedi Imlay	x	x	x	x	x	x	x	x	x	x	x	x	x
E. putnami Imlay			x	x	x	x							
E. aff. tamaulipana Imlay										x			
E. aff. latissima var. *aquila* Brongniart	x												
Gryphaea spp.								x		x	x		
Alectryonia sp.										x			
Trigonia cf. *caudata* Agassiz				x									
T. cf. *ingens* Lycett			x										
T. cf. *carinata* Agassiz			x										
Pecten spp.	x	x								x			
Camptonectes sp.												x	
Syncyclonema sp.	x												
Neithea biangulata Imlay	x			x									
N. cf. *atava* (d'Orbigny)													x
Prohinniles ordoñesi Imlay	x		x	x									
Spondylus oballosensis Imlay			x										
Plicatula umbonata Imlay	x												
P. azulensis Imlay		x											

TABLE 5.—*Distribution of submarginal Neocomian fossils*—Continued

Species	Eastern Coahuila						Eastern Durango						
				Potrero de Menchaca			Cuesta del Carbonera						
	Barril viejo	Sierra de Azul	Potrero de Oballos	Barril viejo shale	Menchaca limestone	Unnamed shale	Loc. A-3	Loc. A-4	N. W. end	Loc. 34	Loc. 37	Locs. 96 and 97	Loc. 98
P. aff. *azulensis* Imlay												x	
P. torreonensis Imlay										x			
P. pulchra Imlay										x	x	x	
P. n. sp. ind.	x												
P. aff. *incongrua* Conrad		x											
Lima (*Plagiostoma*) *kanei* Imlay	x		x										
Gervillia alatior Imlay	x		x										
Astarte durangensis Imlay										x			
A, sp.	x												
Cyprina cf. *bernensis* Leymerie	x												
C. sp. ind.	x												
Trapezium? subtriangulum Imlay										x			
T. diversicostatum Imlay										x			
Lucina kellumi Imlay	x												
Cyclorisma sp										x			
Sphaera americanus Imlay	x		x										
Panope cf. *gurgitis* (Brongniart)	x												
Pholadomya cf. *sanctae-crucis* Pictet and Campiche	x												
P. cf. *gigantea* (Sowerby)	x		x	x									
Harpagodes americanus Imlay	x												
H. mexicanus Imlay	x												
Nerinea sp	x												
Natica cf. *neptuni* d'Orbigny	x												
N. cf. *hugardiana* d'Orbigny	x												
Tylostoma cf. *laharpi* Pictet and Campiche	x												
Vermetus cornejoi var. *variana* Imlay	x			x				x	x	x	x	x	
Trochus n. sp. ind.	x												
Turbo? gigas Imlay	x												
T. n. sp. aff. *mantelli* Leymerie										x			
Pleurotomaria sp											x		
Leopoldia crassicostata Imlay	x												
L. aff. *crassicostata* Imlay		x											
L. truncata Imlay	x												
L. victoriensis Imlay	x												
L. cf. *bakeri* Imlay			x										
Acanthodiscus magnificus Imlay	x												
A. cf. *radiatus* Bruguière	x	x											
Thurmannites cf. *miquihuanensis* Imlay										x			
T. cf. *novihispanicus* Imlay									x				
T. sp								x					
Dichotomites multicostatus Imlay	x												
Lytoceras sp.										x			
Berriasella? sp.									x				
Blanfordiceras? sp									x				

TABLE 6.—*Distribution of newly described ammonites from the offshore deposits of southern Coahuila*

Species	Locality 18	Locality 20	Locality 32	Locality 42	Locality 58
Phylloceras cf. *serum* var. *perlobata* Sayn					x
Distoloceras sp. juv					x
Oosterella? sp				x	
Hemihoplites? mexicanus Imlay		x			x
Mexicanoceras laticostatum Imlay					x
M. multicostatum Imlay					x
Maderia marcosensis Imlay	x				
M. coahuilensis Imlay	x				
M. casitensis Imlay					x
Saynoceras mexicanum Imlay			x		

SYSTEMATIC DESCRIPTIONS

Phylum COELENTERATA

Class ANTHOZOA

Genus *Astrocoenia* Milne-Edwards and Haime 1848

Astrocoenia hispaniensis Imlay, n. sp.

(Plate 1, figures 21, 22)

DESCRIPTION: Corallum massive, irregularly rounded. Corallites polygonal, crowded, and joined directly by their walls. Wall very narrow, upper edge flattened. Calices extremely shallow; diameter ranging from 1.5 to 2 mm. Columella styliform, small, and low. Number of principal septa eight to ten, with smaller septa between. Septa of adjoining corallites may meet end to end or alternate with each other. About seven to nine dissepiments in a space of 5 mm.

REMARKS: This species may be distinguished from *Astrocoenia maloniana* (Vaughan) Cragin (1905, p. 34, pl. II, figs. 1-3) by its consistently shallow calices, its flattened walls between corallites, and its numerous dissepiments.

TYPE: Holotype 19345, Museum of Paleontology, University of Michigan.

OCCURRENCE: Carbonera formation, about 325 feet below top at northwest end of Cuesta del Carbonera, 2 miles south of Las Cuevas, Durango.

Phylum BRACHIOPODA

Class ARTICULATA

Genus *Antiptychina* Zittel 1880

Antiptychina? formosa Imlay, n. sp.

(Plate 2, figures 1-18; text figure 7)

DESCRIPTION: Shell ovate-pentagonal to elongate-pentagonal in outline. Pedicle valve more convex than brachial. Ventrally biplicate. Biplication commences from one-fourth to one-half of the length of the valve from the umbo. Umbo of brachial valve incurved. Lateral commissure slopes dorsally at a slight angle and is then

abruptly recurved near the anterior margin. Linguiform extension not pronounced on most specimens. Umbo of pedicle valve prominent, rounded, incurved, projecting over and close to brachial valve. Beak ridges subangular, mesothyroid, extending about halfway to the postero-lateral margin and almost parallel to hinge. Apical angle 85 to 95 degrees. Shell densely punctate; marked by fine concentric growth lines which become coarser toward the anterior margin.

Dimensions in mm. are as follows:

Specimen	Length	Width	Thickness
Holotype 20930	16.8	15.5	8.5
Paratype 20931	15.1	12.7	7.7
Paratype 20932	14.6	13.0	8.2
Paratype 20933	16.8	13.0	10.0
Paratype 20934	13.2	13.3	6.6
Paratype 20935	17.2	14.0	10.0

The median septum is fairly stout, extends slightly more than one-half the length of the brachial valve, supports the hinge plates throughout their length, and bears connecting bands about 2 mm. from its anterior end. The septalium is moderately deep. Inner socket ridges prominent, overlapping sockets and interlocking with a sulcus on each tooth. Sockets fairly shallow. The loop was traced for 11 mm. in a brachial valve 13 mm. in length. Dental lamellae strong, subparallel.

REMARKS: This species is represented by about 55 specimens which show some variation in dimensions and degree of biplication. It may be distinguished from *Antiptychina? müllerriedi* Imlay (1937, p. 568, pl. 82, figs. 9-24; text figure 4) by its thinner form, higher and less incurved beak, smaller apical angle, shorter beak ridges, and larger pedicle opening.

TYPE: Holotype 20930, paratypes 20931 to 20936, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Sierra de Azul near Candela, Coahuila.

Genus *Rhynchonella* Fischer von Waldheim 1809 *(s. l.)*

"Rhynchonella" durangensis Imlay, n. sp.

(Plate 2, figures 19-36)

1936. *Rhynchonella lacunosa* Kellum, Geol. Soc. Am., Bull., vol. 47, p. 1068.

DESCRIPTION: Shell ovate trigonal in outline. Brachial valve fairly highly convex, with a well-defined median fold anteriorly, which is distinctly demarcated from the convex flanks. Umbo of brachial valve much incurved. Pedicle valve moderately convex, bearing a moderately broad, flattened median sinus which develops from 10 to 11 mm. from the umbo and increases considerably in depth anteriorly. The linguiform extension is broadly U-shaped and tapers slightly forward. Umbo of pedicle valve acute, suberect. Beak ridges are subangular near the umbo and are traceable for a distance of about 5 mm. Interareas broad. Deltidial plates conjunct. Apical angle 80 to 90 degrees. Foramen hypothyrid.

Dimensions in mm. are as follows:

Specimen	Length	Width	Thickness
Holotype 20947	17.0	15.5	10.5
Paratype 20946	17.7	17.4	10.3
Paratype 20945	17.2	15.0	11.2
Paratype 20944	16.0	15.2	11.5
Paratype 20939	16.2	15.5	12.3

Shell ornamented with 11 to 14 rounded costae which begin from 6 to 8 mm. from the umbo, are slightly curved on the flanks, and are strong anteriorly. The species shows considerable variation in the strength of costation. The number of costae in the sinus ranges from two to four and on the fold from three to five. Among

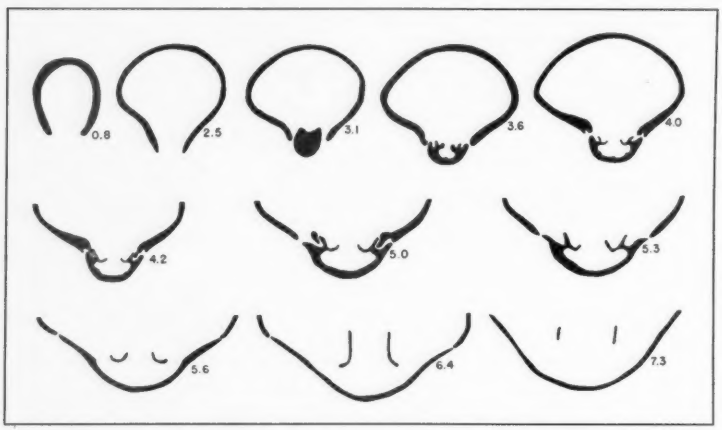

FIGURE 6.—*Transverse sections of "Terebratula" coahuilensis Imlay*
Length of shell, 21 mm. Distance of sections from beak of pedicle valve in millimeters. ×2½.

the 58 specimens in the collections, 42 specimens have four costae on the fold and three in the sinus, 13 specimens have five costae on the fold and four in the sinus, and three specimens have three costae on the fold and two in the sinus. In general the costation is coarsest on the specimens with fewest costae. The variation in costation might be considered as denoting specific differences except for the examples of gradual gradation from one variety to another. Rather inconspicuous growth lines occur on the anterior part of the shell.

The characters of the beak of the pedicle valve are well shown only on the holotype. Transverse sections show internal characters similar to those of *"Rhynchonella" miquihuanensis* Imlay (1937a, p. 570, text figure 6).

REMARKS: This species may be readily distinguished from *"Rhynchonella" lacunosa* Castillo y Aguilera (not Quenstedt) (1895, p. 1, pl. I) by the absence of costae on the upper part of the shell.

TYPE: Holotype 20947, paratypes 20937 to 20939, 20944 to 20946, Museum of Paleontology, University of Michigan.

OCCURRENCE: Carbonera formation. Kellum's localities A-4, A-34, K-96, and K-97 in eastern Durango.

Genus *Terebratula* Müller 1776 *(s. l)*

"Terebratula" coahuilensis Imlay, n. sp.

(Plate 1, figures 1-16; text figure 6)

DESCRIPTION: Shell subpentagonal in outline, about as wide as long, pedicle valve more convex than brachial. Brachial valve fairly convex; anteriorly with a strong

median fold which is divided by a short but well-defined median sinus; flanks fairly strongly sulcate; umbo slightly incurved. Lateral commissure slopes dorsally at a slight angle and is then abruptly recurved ventrally near the anterior margin. Pedicle valve highly convex; anteriorly bearing a broad flattened sulcus which is

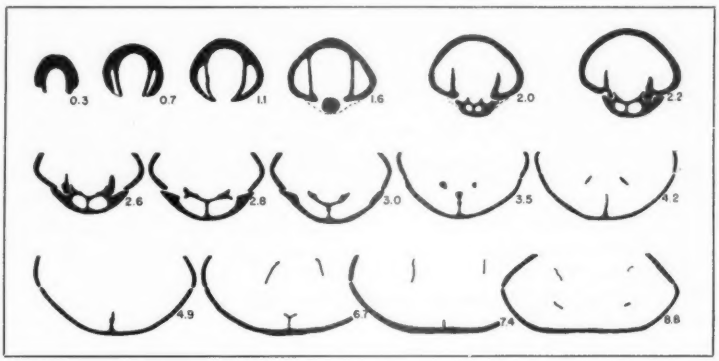

FIGURE 7.—*Transverse sections of Antiptychina? formosa Imlay*
Length of shell, 14.7 mm. Distance of sections from beak of pedicle valve in millimeters. ×2½.

divided by a low median ridge; umbo short, rounded, suberect, becoming slightly incurved in old age. Apical angle 85 to 90 degrees. Foramen circular. Permesothyrid. Symphytium exposed. Beak ridges short, poorly defined. Linguiform extension tapers forward and is about 8 mm. in length. Shell marked by lines of growth arranged at regular and fairly wide intervals; densely punctate.

Dimensions in mm. are as follows:

Specimen	Length	Width	Thickness
Holotype 20926	24.0	25.3	15.0
Paratype 20927	18.6	17.0	10.7
Paratype 20928	18.0	16.0	11.5
Paratype 20929	22.0	21.5	13.2

The sockets are deep and narrow. They are overlapped by the inner socket ridges, which are well demarcated from the gently curved hinge plates. The crural bases are given off ventrally and project nearly at right angles to the hinge plates. The teeth are deeply inserted in the sockets, and the inner socket ridges fit into sulci on the teeth. A projection from the outer socket ridges fits into the denticular cavity. The median septum is low and very short. The dorsal adductor scars appear as low ridges.

REMARKS: The species is represented by 22 specimens which show some variation in the relation of length to width and in the size of the apical angle. It bears a close resemblance to *"Terebratula" carteroniana* d'Orbigny (1847, p. 80, pl. 507, figs. 1-5; Pictet et Campiche, 1872, p. 60, pl. CCI, figs. 1-4) from the Neocomian of Europe but has a larger foramen and appears to be less elongate.

TYPE: Holotype 20926, paratypes 20827 to 20929, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale in Sierra de Azul, Barril viejo, and Potrero de Oballos, Coahuila.

"Terebratula" kanei Imlay, n. sp.

(Plate 1, figures 17-20)

DESCRIPTION: Shell subpentagonal in outline, longer than wide, pedicle valve more convex than brachial. Brachial valve fairly convex; bearing anteriorly a strong median fold which is divided by a short, rather shallow median sinus; flanks moderately sulcate; umbo incurved. Lateral commissure slopes ventrally at a fairly strong angle and is inflected strongly ventrally near the anterior margin. Pedicle valve highly convex, bearing anteriorly a broad, flattened sulcus which is divided by a low median ridge; umbo prominent, rounded, slightly incurved on adult. Apical angle about 75 degrees. Foramen circular, fairly large. Permesothyrid. Beak ridges very short and poorly defined. Linguiform extension tapers forward and is about 9 mm. in length. Shell marked by variable lines of growth which become conspicuous near the anterior commissure; densely punctate. Dimensions of holotype: Length 24.5 mm.; width 20 mm.; thickness 15 mm.

REMARKS: The species is represented by three specimens of which the paratypes are partly corroded and deformed. It may easily be distinguished from *"Terebratula" coahuilensis* Imlay by its more elongate form, more prominent, incurved umbo, less developed folding, and rather blunt line of junction of the valves. The species is named in honor of Wm. G. Kane of Saltillo, Mexico.

TYPES: Holotype 20925, paratype 20940, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Portrero de Oballos near Hermanos and Sierra de Azul near Candela, Coahuila.

Phylum MOLLUSCA

Class PELECYPODA

Genus *Cucullaca* Lamarck 1801

Cucullaca striatiumbonata Imlay, n. sp.

(Plate 3, figures 18-21)

1936. *Cucullaca catorcensis Kellum,* Geol. Soc. Am., Bull., vol. 47, p. 1068.

DESCRIPTION: The species is represented by two specimens. Shell moderate in size, fairly ventricose, equivalve, inequilateral, subtrapezoidal in outline. Dorsal margin straight, making an angle of about 110 degrees with the nearly straight posterior margin; anterior margin regularly rounded, meeting the dorsal margin at nearly a right angle, rounding gradually into ventral margin; ventral margin gently convex, inclined somewhat oblique to dorsal margin, forming a subacute angle with the posterior margin. Beaks moderately separated, strongly incurved, situated about one-fourth the length of the shell from the anterior extremity. An angular carina extends from the beak posteriorly to the postero-ventral extremity. The carina is acute on the beak and becomes obtuse toward the ventral margin. It is paralleled dorsally by a gently concave area. Surface of cardinal area marked by about seven chevron-shaped ligamental grooves. Area elliptical in outline, about one-third as wide as long. Surface ornamented with strong, concentric growth lines and with radiating lines. The latter are raised and especially conspicuous on the umbo and on the anterior slope, becoming fine and inconspicuous on the posterior slope.

Dimensions in mm. are as follows:

Specimen	Length	Height	Convexity
Holotype 20948	57	45	45 (?)
Paratype 15822	70	54	52

REMARKS: This species greatly resembles *C. catorcensis* Castillo y Aguilera (1895, p. 5, pl. IV, figs. 1, 4, and 5) from the Sierra de Catorce of San Luis Potosí, but its beaks appear to be narrower, its anterior margin is more regularly rounded and meets the dorsal margin at a larger angle, its ventral margin is oblique rather than parallel to the dorsal margin, it is proportionately much higher, and its entire shell is covered with radial lines which are not mentioned in the description of the species from Catorce.

TYPE: Holotype 20948, paratype 15822, Museum of Paleontology, University of Michigan.

OCCURRENCE: Carbonera formation. Locality A-34, Sierra de Mapimí, Durango.

Cucullaea gabrielis Leymerie var. *fraterna* Imlay

(Plate 4, figures 1, 2)

DESCRIPTION: The form is represented by five internal molds with portions of the shell material adhering. Shell large, inflated, equivalve, inequilateral, subtriangular in outline. Dorsal margin straight, making an angle of about 120 degrees with the nearly straight posterior margin; anterior margin regularly rounded; ventral margin straight, parallel to dorsal margin, curving up at both ends forming an acute angle with posterior margin. Beaks widely separated, prominent, strongly incurved, situated anterior to the center of the ligamental area and about one-fourth the length of the shell from the anterior extremity. A prominent angular ridge extends from the beak posteriorly to the postero-ventral extremity and bounds a conspicuous concave area on the side of the posterior margin. A much smaller, rounded ridge extends from the posterior side of the beak to near the anterior end of the posterior margin and bounds a small concave area lying next to the cardinal area. A poorly defined ridge extends from the anterior side of the beak to the antero-basal margin and encloses a shallow depression. Anterior and posterior margins near cardinal area rather strongly keeled. Surface of cardinal area marked by 16 or 17 strongly impressed chevron-shaped ligamental grooves and with several transverse grooves of which the most prominent are near the posterior end. Area elliptical in outline, about three-fifths as wide as long. Surface ornamented with strong, concentric growth lines and with radiating striae.

Dimensions of figured specimen: Length, 110 mm.; height, 65 mm.; convexity, 85 mm.

REMARKS: The Mexican specimens described above are remarkably similar to *Cucullaea gabrielis* Leymerie (1842, p. 6; pl. 7, figs. 5a-c) from the Neocomian of Europe and South America. The latter species has recently been described in detail by Weaver (1931, p. 192-195; pl. 13, fig. 52; pl. 14, figs. 56, 57). Possibly the Mexican variety comes within the form range of *C. gabrielis* but judging from illustrations the Mexican variety has a more angular umbonal ridge, a shorter anterior margin, a more depressed and wider cardinal area, more ligamental grooves, and deeper concave areas on the sides of the posterior margin. In these respects it is more like the types figured by Leymerie. *C. gabrielis* Leymerie is placed by Gillet (1924, p. 17) in *Idonearca* Conrad.

Specimen No. 20728, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Genus *Plicatula* Lamarck 1819

Plicatula pulchra Imlay, n. sp.

(Plate 3, figures 1-9, 14-17)

DESCRIPTION: The species is represented in the University of Michigan collection by several hundred well-preserved specimens from the Sierra de Mapimí, Durango.

Shell subovate to trigonal-ovate in outline, slightly inequilateral, the height greater than the length; right valve moderately to strongly inflated, with small to medium attachment scars which do not obscure the ornamentation; left valve flat or concave; margins even.

Surface ornamented with numerous, fine, close-set radial ribs of nearly equal strength and with irregularly spaced growth lines which mark constrictions of variable strength. As a consequence of the variability of the growth lines, some shells are fairly even, and others are strongly rugose. Radial ribs slightly wavy and crenulated, spinate; increasing in number by bifurcation and implantation; about 120 to 150 on right valves. Exceptionally some specimens (Pl. 3, fig. 14) bear ribs of two sizes near the beaks.

Dimensions in mm. are as follows:

Specimen	Length	Height	Convexity of both valves
Holotype 20606	18.5	21.0	7.0
Paratype 20607	22.5	22.5	9.0
Paratype 20608	23.0	28.0	10.5
Paratype 20610	15.5	17.0	7.0
Paratype 20611	20.0	18.5	8.5
Paratype 20612	19.0	21.0	10.0
Paratype 15803	18.5	20.0	8.0

REMARKS: This species is characterized by its exceedingly fine, close-set ribs which have about equal strength on all parts of the shell. The degree of rugosity appears to be related to individual growth rather than to specific variation. A closely comparable European species is *Plicatula (Atreta) strambergensis* Boehm (*see* Gillet, 1924, p. 59, pl. 1, figs. 8a-c) which ranges from the Tithonian to the Hauterivian.

TYPE: Holotype 20606, paratypes 20607, 20608, 20609, 20610, 20611, 20612, 15803, Museum of Paleontology, University of Michigan.

OCCURRENCE: Carbonera formation. Localities A-34, A-37, K-96, and K-97, Sierra de Mapimí, Durango.

Plicatula torreonensis Imlay, n. sp.

(Plate 2, figures 41, 42)

DESCRIPTION: The species is represented by one specimen. Shell trigonal-ovate in outline, slightly inequilateral, the height greater than the length; right valve weakly convex in early stages, becoming more convex in later stages, bearing small attachment scar; left valve slightly concave; margins even.

Surface of right valve in early stages marked with faint growth lines and with a few widely spaced, slender, moderately prominent, slightly sinuous, radial ribs which increase in number by intercalation until, at a height of 15.5 mm., there are eleven fairly long ribs and six short ribs. In later stages the surface is marked by several pronounced concentric constrictions and by numerous, fine, weakly spinate, ribs which are only slightly narrower than the interspaces. Surface of left valve ornamented similar to right, but ribs and constrictions are not as prominent.

Dimensions: Length 18 mm.; height 20.5 mm.; thickness 6 mm.

REMARKS: This species may be distinguished from *P. pulchra* Imlay by its coarser ribbing and less convex right valve.

TYPE: Holotype 15815, Museum of Paleontology, University of Michigan.

OCCURRENCE: Carbonera formation. Locality 34 on west side of Sierra de Mapimí. Durango.

Plicatula umbonata Imlay, n. sp.

(Plate 3, figures 10-13, 22)

DESCRIPTION: The species is represented by 12 specimens. Shell elongate, ovate to elongate trigonal in outline, slightly inequilateral, the height much greater than the length. Right valve strongly inflated, especially in the umbonal region; beak prominent, narrow, more or less strongly incurved; attachment scar small. Left valve slightly concave, surface uneven. Margins even.

Surface ornamented by numerous, close-set, flexuous, radiating striae of nearly equal strength and with irregularly spaced growth lines which mark constrictions of variable strength. Radial striae increase in number by bifurcation and implantation.

Dimensions in mm. are as follows:

Specimen	Length	Height	Convexity
Holotype 20787	15.5	20	7
Paratype 20786	14.0	23+	11
Paratype 20784	17.0	30	11

REMARKS: The shape of the shell and the incurved beak of the right valve at first suggested that this species belonged to the genus *Gryphea,* but its ornamentation clearly indicates a position near *Plicatula pulchra* Imlay. It is distinguished from the latter by finer ornamentation and a more elongate, more convex shell.

TYPE: Holotype 20787, paratypes 20788, 20786, 20785, 20784, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Plicatula azulensis Imlay, n. sp.

(Plate 2, figures 37-40)

DESCRIPTION: The species is represented by six specimens. Shell trigonal ovate in outline, slightly inequilateral, the height and length about equal; right valve weakly convex in early stages, becoming more convex in later stages, bearing moderately large attachment scar; left valve concave; margins even.

Surface of right valve ornamented with about 16 slender, moderately prominent, slightly sinuous, radial trending ribs which become coarser anteriorly. Between these ribs lie finer, radial ribs which number from one to three for each interspace near the posterior end of the valve and from five to eight at the anterior end. These finer ribs increase in number by intercalation and bifurcation and do not become coarser anteriorly. Both sets of ribs are crenulated and weakly spinate. Moderately pronounced, concentric growth constrictions occur at wide intervals. Surface of left valve ornamented similarly to right, but the two sets of ribs are more nearly equal in size and more spinate.

Dimensions of holotype: Length, 19 mm.; height, 19 mm.; thickness, 5.7 mm.

TYPE: Holotype 20942, paratype 20941, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Sierra de Azul, near Candela, Coahuila.

Genus *Spondylus* Linnaeus 1758

Spondylus oballosensis Imlay, n. sp.

(Plate 20, figures 1-3)

DESCRIPTION: The species is represented by one specimen. Shell fairly large for genus, inequivalve, inequilateral, obliquely ovate in outline, height greater than length, valves moderately and about equally convex; anterior part poorly preserved. Right valve ornamented with strong, closely-spaced, spinate, radial ribs and by fairly strong concentric growth lamellae. Left valve ornamented with two sets of spinate ribs arranged alternately; stronger ribs somewhat narrower and weaker than ribs on the right valve and bearing smaller, more pointed spines; weaker ribs spinate near ventral margin. Concentric growth lamellae less developed on left than on right valve. Ears not preserved.

Dimensions of holotype: Length, 50 mm.; height (incomplete), 55 mm.; thickness of both valves, 26 mm.

REMARKS: This species is characterized by its strong ornamentation and nearly equally convex valves. It does not bear a close resemblance to any Lower Cretaceous species known to the writer.

TYPE: Holotype 21129, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale, Potrero de Oballos, Coahuila.

Genus *Pecten* Müller 1776

Pecten (Camptonectes) aff. *insutus* Cragin

(Plate 3, figure 23)

REMARKS: Two specimens approach closely to *P. insutus* Cragin (1905, p. 44, pl. IV, figs. 11, 12) but appear to have coarser ribbing and less pronounced concentric growth lines.

FIGURED SPECIMEN No. 20949, Museum of Paleontology, University of Michigan.

OCCURRENCE: Carbonera formation. Locality A-34, Sierra de Mapimí, Durango.

Genus *Neithea* Drouet 1824

Neithea biangulata Imlay, n. sp.

(Plate 4, figures 7, 8; Plate 20, figures 6, 7)

DESCRIPTION: The species is represented by six specimens which show only the right valve. Shell subtriangular in outline, slightly inequilateral. Ventral margin convex, with incisions between the main ribs. Upper margins of dorsal slopes diverge from the beak at an angle of 40 to 45 degrees and are slightly convex. Right valve highly convex; beak much incurved and sharp; ears partly defective, the anterior one separated from body of shell by a weak sulcus. Surface of right valve ornamented with 11 to 13 subequal, prominent, rounded ribs which are separated by somewhat broader, concave interspaces. The central seven ribs are much stronger than the ribs on the dorsal slopes, and the outermost of the central seven ribs are especially prominent. In the inner spaces and on the sides of the ribs may occur from one to three weak ribs. The entire surface is covered with extremely fine radial striae. Numerous extremely fine, equal, concentric growth lines cross both ribs and interspaces.

Dimensions of holotype: Length (estimated) 60 mm.; height (incomplete) 63 mm.; convexity 32 mm. Dimensions of paratype U. M. 20731 given in same order are 21.5 mm., 24.5 mm., and 12 mm.

REMARKS: This species apparently belongs to the branch of *Neithea aequicosta* (d'Orbigny) (Gillet, 1924, p. 53) in which the intercalary ribs are almost as strong as the principal ribs.

TYPE: Holotype 19365, paratype 20731, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo and Potrero de Menchaca, Coahuila.

Genus *Prohinnites* Gillet 1921

Prohinnites ordoñesi Imlay, n. sp.

(Plate 5, figures 1, 2; Plate 6, figure 1; Plate 7, figure 1)

DESCRIPTION: The species is represented by 13 imperfect specimens. Shell large, subovate in outline, inequilateral, inequivalve. Right valve convex, especially in umbonal region; beak (preserved only on one small specimen) small, not projecting beyond hinge line; ears poorly preserved, not distinctly separated from umbo. Left valve concave in its upper part, corresponding to an early *Pecten*-like stage; remainder of valve depressed convex or nearly flat; ears distinctly separated from umbo. Hinge and internal characters not known. Anterior and posterior margins sinuous due to curvature toward right valve.

Surface of right valve covered with rounded, knotted, radial ribs of several sizes and with concentric growth lines. Ribs coarsest on umbo and on immature specimens, becoming broader and lower toward the margins. Additional ribs arise by implantation and furcation. Near the peripheral zone of the holotype occur about 12 primary and 14 secondary ribs. Tertiary ribs occur only on the umbonal region. Concentric ornamentation is visible only on the peripheral zone.

Surface of left valve in early stages marked with fine radial ribs of two sizes. Later ornamented like right valve, but the ribbing is weaker and the growth lines more prominent.

Dimensions in mm. as follows:

Specimen	Length	Height	Convexity
Holotype 20442	145 (?)	140 (?)	50
Paratype 20390	150	140	50

REMARKS: This species is similar to *Prohinnites leymerii* Deshayes (Leymerie, 1842, p. 10, Pl. 14, fig. 1; Pictet and Campiche, 1870, p. 224, Pl. CLXXIV, CLXXV) from the Hauterivian of Europe but is distinguished by a smaller number of secondary ribs. *P. renevieri* (Coquand) (Pictet and Campiche, 1870, p. 227, pl. CLXXVI) has coarser ribbing and nearly the same ornamentation on both valves. This species is named in honor of Ezequiel Ordoñez of Mexico City.

TYPE: Holotype 20442, paratype 20390, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Potrero de Oballos near Hermanos, Potrero de Menchaca, and just below Padilla limestone at Barril viejo, Coahuila.

Genus *Gryphaea* Lamarck 1801

Gryphaea sp. ind.

(Plate 8, figures 1-6)

DESCRIPTION: Thirteen specimens of *Gryphaea* apparently representing several species, were obtained from the lower Neocomian beds at Locality A-34 on the western side of the Sierra de Mapimí, Durango. Species of oysters should not be estab-

lished until large numbers of specimens are available. However, as *Gryphaea* (*s. s.*) is unknown from the Lower Cretaceous of Europe and has not been recorded from the lower Neocomian of Texas, these Mexican forms are worthy of brief description.

The form figured on Plate 8, figures 1 and 2, is semicircular in outline and depressed. The beak of the left valve is depressed and weakly incurved. The right valve is concave near the posterior margin and fits within the left valve. A faint sinus occurs near the antero-ventral margin. Several specimens which appear to belong to the same species as the above form have more convex umbos.

The form figured on Plate 8, figures 3 and 4, is ovate in outline. Its left valve is highly convex, has a moderately incurved beak, and somewhat resembles immature forms of *G. corrugata* Say. On Plate 8, figures 5 and 6, is shown a larger form which is distinguished from the preceding by a marginal flare and a weak sinus but possibly represents the same species.

SPECIMEN NOS.: 15805, 15826, 15810, 15944. Museum of Paleontology, University of Michigan.

Genus *Exogyra* Say 1820

Exogyra reedi Imlay

(Plate 9, figures 4-6; Plate 12, figures 1, 2; Plate 13, figures 1-5)

1937. *Exogyra reedi* Imlay, Journal of Paleontology, Vol. 11, no. 7, p. 566, pl. 77, figs. 1-6; pl. 78, figs. 1-7.

REMARKS: *Exogyra reedi* Imlay was based on specimens obtained near Miquihuana, Tamaulipas, where it is associated with ammonites which indicate a Valanginian age for the enclosing strata (Imlay, 1937a, 557-558, 566). A similar form was noted as occurring in strata of uncertain age in the Sierra de Mapimí of eastern Durango and in the region of Cuatro Cienegas of east-central Coahuila. The age of the strata in question has subsequently been determined as Neocomian, those in eastern Durango being, probably, of Valanginian age (Imlay, 1938b, p. 1684-1685), and those in east-central Coahuila including horizons as young as lower Hauterivian. Studies of the faunas in these three regions show that *Exogyra reedi* Imlay is represented in all by numerous variations. In general the variations center around a stout or a slender form, but these are connected by many transitions. Stout forms are most common in eastern Durango, but slender forms predominate in the other two regions. Most of the specimens (approximately 200) in the University of Michigan collections are smoothly sculptured except for nodulations on the umbonal ridge (Pl. 12, figs. 1, 2). Only one (Pl. 13, figs. 2, 3) bears a weak wing-like expansion on its anterior margin, and only a few on their posterior margins. Several specimens bear weak folds antero-ventral to the umbonal ridge. The hinge is narrow (Pl. 13, fig. 4) and has a well impressed ligamental groove which is curved to conform with the twist of the shell. Posterior to the groove is a depression. The adductor scar is oval in outline, situated below the midheight and on the posterior side of the shell.

In its highly variable form *E. reedi* Imlay resembles *E. couloni* (Defrance) (d'Orbigny, 1847-1849, p. 698-701, pls. 466, 467, figs. 1-3; Bigot, 1903, fiche 9) from the Neocomian of Europe but can hardly be considered identical. Judging from the many published descriptions and figures of *E. couloni* (Defrance), the Mexican species may be distinguished by rarity of wing-shaped expansions and oblique folds, a higher and narrower umbonal ridge, more common concavity of the posterior side, and generally smooth sculpture. Undoubtedly some specimens of *E. reedi* would compare closely with some of *E. couloni*, but the characteristics of the majority

of specimens justify a separation. Certainly *E. reedi* is distinct from the larger, rounder, and more weakly carinated *E. aquila* (Brongniart) (d'Orbigny, 1847-49, p. 706-708, pl. 470) which Pictet and Campiche (1871, p. 287-293) considered identical with *E. couloni* (Defrance), and Pervinquière (1912, p. 176-179) considered synonymous with *E. latissima* (Lamarck) (Pervinquière, 1910, fiche 194). Pictet and Campiche (1871, p. 290-292) showed that during the Neocomian the narrow, strongly carinate forms usually called *E. couloni* predominated but that large, less strongly carinate forms, like *E. aquila* were present. During the Aptian, however, large forms called *E. aquila* were common, and the narrow forms were rare. Finally, in the lower Albian existed even larger, flatter, more subcircular forms which were very weakly carinated. These conclusions were substantiated by Pervinquière (1910, fiche 194; 1912, p. 176-179) and Woods (1913, p. 395-404). There appears, therefore, to have been in Europe a gradual development from a triangular, strongly carinated form in the lower Neocomian to a subcircular, nearly noncarinated form in the lower Albian. To this series of forms the name *E. latissima* (Lamarck) has been applied frequently in recent publications, whereas the names *E. aquila* and *E. couloni* designate the most common varieties.

A similar development apparently occurred during the Lower Cretaceous in the waters of the Mexican geosyncline. The Mexican Neocomian deposits contain an abundance of *Exogyra reedi* Imlay which corresponds to the European *E. couloni* (Defrance). The Mexican late Aptian, or early Albian, contains an undescribed form which may prove to be identical with the European *E. aquila* (Brongniart). It has been collected (1) By Wm. G. Kane in the Potrero de Oballos near Hermanos, Coahuila, from beds below the "Glenrose" limestone, and (2) by the writer in Cañon de Santa Rosa a few miles southeast of El Tigre, Sonora.

HYPOTYPES: 15814, 20453, 20393, 20564, 20568, 20567, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale at Barril viejo, Sierra de Azul, and Potrero de Oballos, Coahuila; Menchaca limestone and lowest beds of section at Potrero de Menchaca, Coahuila; Carbonera formation at A-3, A-4, A-34, A-37, and K-96, K-98 in eastern Durango; basal Cretaceous beds near Miquihuana, Tamaulipas.

Genus *Trigonia* Bruguière 1789

Trigonia spp.

(Plate 20, figures 4, 5)

REMARKS: Seven poorly preserved specimens of *Trigonia*, representing as many species, have been obtained from the Barril viejo shale at various localities in eastern Coahuila. The sections Clavellatae, Quadratae, Scabrae, and Byssiferae are represented by three, one, two, and one species respectively. One species from Potrero de Oballos is similar to *T. ingens* Lycett (1872, p. 24, pl. VIII, figs, 1-3; 1877, p. 207, pl. XXXVI, figs. 5, 6). A species from Potrero de Menchaca is similar to *T. caudata* Agassiz (Lycett, 1875, p. 129, pl. XXVI, figs. 5-7; d'Orbigny, 1843, p. 133, pl. 287). Another species (pl. 20, figs. 4, 5) from Potrero de Oballos greatly resembles *T. carinata* Agassiz (Lycett, 1877, p. 179, pl. 35, figs. 3-6) but is not so high as is typical of that species.

FIGURED SPECIMEN No.: 21130, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale, at Barril viejo, Potrero de Oballos, Potrero de Menchaca, and Sierra de Azul.

Genus *Lima* Bruguière 1792

Subgenus *Plagiostoma* Sowerby 1814

Lima (*Plagiostoma*) kanei Imlay, n. sp.

(Plate 8, figure 7; Plate 9, figures 1-3)

DESCRIPTION: The species is represented by eight specimens. Shell subovate to subtrigonal in outline, oblique, equivalve, considerably inequilateral, compressed. Antero-dorsal slope straight or slightly concave, steep, and moderately long; postero-dorsal slope steeper and shorter. Ventral margin gently convex, rounding gently into posterior and anterior margins. Beaks small, close together. Apical angle 90 to 105 degrees. Posterior ear fairly large, triangular, elongate; anterior ear not seen. Anterior area depressed, long, fairly narrow, and marked with radial ribs. Surface ornamented by many low, concentric growth undulations and by broad, slightly rounded, radial, undulating ribs which are separated by narrow grooves. Radial ribs present only on the anterior and posterior margins and on the umbones, but the extent of the rib bearing area varies on different specimens.

Dimensions in mm. as follows:

Specimen	Length	Width	Thickness
Holotype 20409	77(?)	58	26
Paratype 13848	66(?)	57	..
Paratype 20427	88(?)	..	27(?)
Paratype 13861	70	70	..

REMARKS: *Lima kanei* Imlay is characterized by its large size and the restriction of radial ribs to the margins. Its ornamentation is similar to that of the Upper Cretaceous *L. simplex* d'Orbigny (1847-1849, p. 545, pl. 418, figs. 5-7), but the two species differ considerably in the other respects. *L. difficilis* d'Orbigny (1847-1849, p. 560, pl. 423, figs. 10, 11) from the Senonian of France is more elongate and compressed. *L. aubersonensis* Pictet and Campiche (1870, p. 140, pl. 164, figs. 1, 2) from the Valanginian of Europe approaches the Mexican species even closer but has more extensive ribbing and a thicker form. However, variability in extent of ribbing is characteristic of the species similar to the Mexican form and is of doubtful aid in making specific distinctions. *L. multilineata* Stanton (1895, p. 36, pl. II, figs. 4, 5) from the lower Neocomian of California (Anderson, 1938, p. 111) is more obliquely elongated and more coarsely ribbed.

TYPE: Holotype 20409, paratypes 13861, 20427, 13848, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shales. Barril viejo and Potrero de Oballos, Coahuila.

Genus *Gervillia* Defrance 1820

Gervillia alatior Imlay, n. sp.

(Plate 10, figures 1, 2; Plate 11, figures 1-6)

DESCRIPTION: The species is represented by 64 specimens from Barril viejo, Coahuila.

Shell inequivalve, inequilateral, obliquely elongated, triangular rhombic, anterior and posterior margins sigmoidal in outline. Left valve fairly convex, distinctly larger than right valve; its beak small, pointed, curved forward and downward and projecting slightly beyond the hinge line; its postero-ventral part turned backward

and a little upward; anterior wing small, projecting, separated from beak by an abrupt depression; posterior wing broad, triangular, strongly projecting, distinctly separated from body of shell. Right valve less convex and less developed than left valve; beak less prominent and barely reaching hinge line. Hinge line straight, apparently as long as the greatest antero-posterior diameter, and forming an angle of 55 to 70 degrees with the umbonal ridge; hinge area moderately wide, with seven or eight large cartilage pits of which most are narrower than the spaces between them.

Surface of shell ornamented with distinct growth lines and radial ribs which are invariably stronger on the left than on the right valve. The radial ribs vary greatly in prominence and spacing on different specimens. They are strongest on the umbones, become broader and fainter ventrally and posteriorly, and are lacking on the anterior wings and on some right valves. They are separated on the umbones by much finer radiating ribs.

Dimensions in mm. are as follows:

Specimen	Estimated length	Estimated height	Thickness of both valves
Paratype 20622	66	67	39
Paratype 20377	75	77	45
Paratype 20624	60	65	..
Holotype 20625	..	100	66

REMARKS: This species is similar to *G. corrugata* Cragin (1905, p. 46, pl. IV, figs. 8-10) but is more strongly ribbed, its wings are more distinctly set off from the body of the shell, and it is elongated less obliquely to the hinge line. The immature form of *G. alaeformis* (Sowerby) (1819, p. 93, pl. CCLI; Woods, 1905, p. 79, pl. XI, figs. 9a-d, 10a-d, 11, text figures 9-14) is similar to *G. alatior* Imlay, but the adult forms lack the radial ornamentation and wing-like projection of the posterior ear. A strongly ribbed form from the Neocomian of Argentina, described by Weaver (1931, p. 201, pl. 15, figs. 62-63) as *G. alaeformis* (Sowerby), appears to be nearly identical with the Mexican form.

TYPE: Holotype 20625, paratypes 20377, 20624, 20622, 20626, 20623, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Potrero de Oballos, just below Padilla limestone, west side of Barril viejo, and about 300 feet below Padilla limestone, center of Barril viejo Coahuila.

Genus *Astarte* Sowerby 1816

Astarte durangensis Imlay, n. sp.

(Plate 8, figures 10, 11)

DESCRIPTION: The species is represented by one specimen whose ventral part has been faulted laterally. Shell elongate, ovate in outline, moderately convex, most inflated slightly above the midheight, equivalve, very inequilateral. Dorsal margins diverge from beaks at an angle of about 115 degrees. Anterior margin regularly rounded; ventral margin gently convex; posterior margin defective below at the extremity, meeting the dorsal margin at a wide subobtuse angle. Beaks fairly prominent, incurved, close together, situated above one-third the length of the shell from the anterior extremity. A weak umbonal ridge is restricted to upper part of the postero-dorsal slope. Lunule and escutcheon distinct. Margins of valves crenulated. Surface marked by strong, subequal, concentric ribs which are widely spaced

on the umbo and closely spaced on the main body of the shell. Dimensions: Length, 30 mm.; height, 22 mm.; thickness, 14.5 mm.

REMARKS: This species is a little like *A. elongata* d'Orbigny (1847-1849, p. 68, pl. 263, figs. 8-11) from the Neocomian of Europe but has a much more prominent beak and is more inflated. *A. californica* Stanton (1895, p. 57, pl. VI, figs. 19-21) from the Neocomian of California has a narrower umbo, finer ribbing, and is less elongate.

TYPE: Holotype 15819, Museum of Paleontology, University of Michigan.

OCCURRENCE: Carbonera formation. Locality 34 on west side of Sierra de Mapimí, Durango.

Genus *Cyprina* Lamarck 1818

Cyprina cf. *bernensis* Leymerie

REMARKS: Six more or less crushed internal molds with parts of the shell adhering gently resemble *C. bernensis* Leymerie (1842, p. 5, pl. 5, figs. 6a, b; d'Orbigny, 1847-1849, p. 98, 759, pl. 271) but are probably slightly more elongate and thinner.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Genus *Trapezium* Megerle v. Mühlfeldt 1811

Trapezium? diversicostulatum Imlay, n. sp.

(Plate 6, figures 2-4)

DESCRIPTION: The species is represented by one specimen whose postero-ventral extremity is defective. Shell moderately large for genus, ventricose, subtrapezoidal in outline, equivalve, very inequilateral. Antero- and postero-dorsal margins diverging from the apex at an angle of about 100 degrees, the former slightly concave, the latter long and gently convex. Anterior margin rather narrowly rounded; ventral margin broadly rounded. Beaks prominent, fairly small, incurved, prosogyrate, a little separated, situated in front of the midlength. An angular umbonal ridge extends from the beak toward the lower posterior extremity, forming the anterior limit of the steeply inclined, concave postero-dorsal slope. The ridge is paralleled anteriorly by a distinct, shallow depression which originates on the umbonal slope. Antero-dorsal slope abrupt, excavated toward the beak. Lunule cordate. Surface marked with concentric lines of growth which are of variable strength and irregularly spaced on the main body of the shell but are regularly spaced and similar in strength on the postero-dorsal slope. No radial ornamentation is observable on the type. Dimensions: Length (estimated), 24 mm.; height, 22 mm.; thickness, 17 mm.

REMARKS: As in most Cretaceous species assigned to *Trapezium*, the hinge is not known, and the generic determination is therefore uncertain. However the general form of the shell and the position of the beaks agree more closely with *Trapezium* than with similar genera such as *Veniella* and *Cyprina*. *Trapezium truncatum* Stephenson (1923, p. 267, pl. LXXIV, figs. 2-5) has less anteriorly placed beaks.

TYPE: Holotype 15830, Museum of Paleontology, University of Michigan.

OCCURRENCE: Carbonera formation. Locality A-34 on west side of Sierra Mapimí, Durango.

Trapezium? subtriangulum Imlay, n. sp.

(Plate 6, figures 5, 6)

DESCRIPTION: The species is represented by one slightly deformed specimen. Shell large for genus, not very ventricose, subtrapezoidal in outline, equivalve, very inequilateral. Antero- and postero-dorsal margins diverging from the apex at an

angle of about 85 degrees, the former slightly concave, the latter long and gently convex. Anterior margin long, nearly vertical, rounding rather abruptly into ventral margin to which it lies at a right angle; ventral margin long and nearly straight, becoming slightly concave just posterior to its midlength; posterior margin truncated nearly vertically, meeting the ventral margin at an angle of about 80 degrees. Beaks fairly prominent, small, incurved, a little separated, situated near the anterior extremity. An angular umbonal ridge extends from the beak to the lower posterior extremity, separating the steeply inclined, concave postero-dorsal slope from the main body of the shell. The ridge is paralleled anteriorly by a very broad, shallow depression which originates on the umbonal slope. Anterior dorsal slope abrupt, slightly excavated below the beaks. Lunule ovate, depressed. Surface marked with fine, narrow, fairly regular lines of growth which become finer toward the dorsal margin. No radial marking present. Dimensions, Length, 26.5 mm.; height, 21.5 mm.; thickness, 13 mm.

REMARKS: This species may be distinguished from *T. diversicostulatum* Imlay by its more elongate, less ventricose form and the nearly terminal position of the beaks.

TYPE: Holotype 20732, Museum of Paleontology, University of Michigan.

OCCURRENCE: Carbonera formation. Locality 34 on west side of Sierra de Mapimí, Durango.

Genus *Lucina* Bruguière 1797

Lucina kellumi Imlay, n. sp.

(Plate 4, figures 3-6)

DESCRIPTION: The species is represented by two specimens. Shell fairly large for genus, equivalve, subequilateral, broadly subovate in outline, fairly convex. Anterior margin truncated above, passing by a subobtuse angle into the broadly convex ventral margin; posterior margin subtruncated, rounding broadly into the ventral and dorsal margins; dorsal margin slightly arched back of beak, slightly concave in front of beak. Beaks fairly low, incurved, close together, slightly prosogyrate, situated a little in advance of the midlength. Lunule ovate, depressed, limited by a carina. Escutcheon large, distinctly limited. Surface bears numerous concentric, irregularly spaced ribs which become smaller near the dorsal margin.

Dimensions in mm. as follows:

Specimen	Length	Height	Thickness
Holotype 20730	34	30	19.5
Paratype 20431	44	38	24.5(?)

REMARKS: This species is similar in form and ornamentation to *Lucina dupiniana* d'Orbigny (1847-1849, p. 117, pl. 281, figs. 6-8) from the Neocomian of Europe but may be distinguished by its lower beak, slightly less inflated form, and depressed lunule.

TYPE: Holotype 20730, paratype 20431, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Genus *Sphaera* Sowerby 1822

Sphaera americanus Imlay n. sp.

(Plate 7, figures 2, 3; Plate 8, figures 8, 9)

DESCRIPTION: The species is represented by 14 specimens. Shell subovate in outline, equivalve, inequilateral, highly convex, most inflated slightly above midheight.

Anterior margin regularly rounded, passing gradually into broadly rounded ventral margin. Posterior margin rounding regularly below, rounding fairly abruptly above into gently convex dorsal margin. Beaks prominent, strongly incurved, close together situated from one-fourth to two-fifths the length of the shell from the anterior extremity. Lunule depressed. Escutcheon triangular, adductors scars large, moderately impressed.

The ornamentation consists of strong, concentric, unequal ribs with sharp summits separated by broader furrows, on both of which are numerous small concentric ribs. On some specimens occur radial striations.

Dimensions in mm. as follows:

Specimen	Length	Height	Thickness
Holotype 20421	62	59	51
Paratype 20445	78	71	66
Paratype 20414	94	80	76

REMARKS: This species varies considerably in thickness and in the position of the beaks. It greatly resembles the highly variable *Sphaera corrugata* Sowerby (1822, p. 42, pl. 335) which ranges through the Neocomian and Aptian of Europe (Woods, 1907, p. 157, pl. XXIV, fig. 24, pl. XXV, figs. 1, 2, text-fig. 26; Gillet, 1921a, p. 14, pl. 1, fig. 15; Gillet, 1924, p. 124) but is less globular, more inequilateral, and has weaker radial markings. Its generic position must remain uncertain until the character of the hinge plate is known. It possibly belongs to the genus *Mactromya* Agassiz (equals *Unicardium* d'Orbigny according to Arkell, 1934, p. 305).

TYPE: Holotype 20421, paratype 20445, 20414, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Potrero de Oballos and just below Padilla limestone, Barril viejo, Coahuila.

Genus *Panope* Menard 1807

Panope cf. *gurgitis* (Brongniart)

(Plate 6, figures 7, 8)

DESCRIPTION: The species is represented by one slightly deformed specimen which lacks a small part of its posterior end. It is subelliptical-elongate, equivalve, inequilateral, moderately convex. Anterior margin rounded; posterior margin probably rounded; ventral margin gently convex; postero-dorsal margin nearly straight. Beaks broad, moderately prominent, incurved, situated about one-fourth the length of the shell from the anterior extremity. Shell in front of beaks depressed slightly.

Ornamentation consists of fairly strong, rounded, concentric growth undulations. Dimensions: Length 52 mm., height 30 mm., thickness 22 mm.

REMARKS: This species is much like *P. gurgitis* (Brongniart) (*see* Woods, 1909, p. 222, pl. XXV, figs. 9-14; pl. XXXVI, figs. 1-8) which ranges through most of the Lower Cretaceous of Europe. It lacks the fine radial ornamentation commonly present on the latter and perhaps has a broader umbo. However the European species is highly variable in ornamentation, shape, and position and size of the umbo, and possibly includes varieties like the Mexican form.

SPECIMEN NO.: 20416, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Genus *Pholadomya* Sowerby 1825

Pholadomya cf. *sanctae-crucis* Pictet et Campiche

(Plate 12, figures 3-5)

DESCRIPTION: The Mexican species is represented by four specimens. Shell fairly large, equivalve, inequilateral, elongate, subelliptical to subrectangular in outline, ventricose. Valves not gapping. Hinge line long and straight. Anterior margin meeting the hinge line nearly at a right angle, rounding backward obliquely and gradually into the gently convex ventral margin; posterior margin broad, nearly vertical, rounding into ventral margin at a subobtuse angle, rounding abruptly into dorsal margin at nearly a right angle. Beaks large, moderately prominent, incurved, close together, situated at the anterior extremity or within one-eighth the length of the shell from the anterior extremity. Surface marked by fairly strong concentric growth lines and undulations. The three largest specimens, comparable in size with the largest figured, bear a wide, shallow radial groove on the anterior part of the shell below the umbo. A smaller specimen (Pl. 12, fig. 3) bears several broad, faint radial grooves.

Dimensions in mm. as follows:

Specimen	Length	Height	Thickness
15979	81	65 (?)	57
20417	53	40	38 (?)

REMARKS: The variation in position of the beaks is shown by the figured specimens. The species greatly resembles *P. sanctae-crucis* Pictet et Campiche (1865, p. 82, pl. 105, figs. 6, 7; Moesch, 1874, p. 87, pl. 33, fig. 5) from the Valanginian of France. A similar form, identified by Weaver (1931, p. 317, pl. 36, figs. 202, 203) as *P. sanctae-crucis* occurs in the Neocomian deposits of Argentina. Judging from the published figures of *P. sanctae-crucis*, the Mexican form appears to have a broader posterior margin which rounds more abruptly into the hinge line, and its beaks are situated nearer the anterior extremity of the shell. But, as only a few specimens are available, these differences might be ascribed to deformation. Certainly the striking resemblances with forms as remote as Argentina and France are noteworthy. Compared with the Mexican form, *P. marcoui* Cragin (1905, p. 80, pl. XVI, figs. 1, 2) is much smaller, more elongate, and has narrower, more numerous radial ribs. *P.* aff. *paucicosta* Roemer (*in* Cragin, 1905, p. 81, pl. XVI, figs. 5, 6) has more elevated beaks and a deeper escutcheon.

SPECIMEN NOS.: 15979, 20417, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Pholadomya cf. *gigantea* (Sowerby)

(Plate 18, figure 5)

REMARKS: A dozen poorly preserved specimens are greatly similar to *P. gigantea* (Sowerby) (*see* Woods, 1909, p. 246, pl. XL, fig. 14; pl. XLI, fig. 1) which ranges through the Neocomian and Aptian of Europe. The shell is elongate, curved, and has numerous narrow, sharp, radial ribs except at the extreme anterior and posterodorsal margins. Compared with *P. tosta* Cragin (1905, p. 79, pl. XV, figs. 2, 3) the Mexican form is more elongate, has a greater area covered with ribs, and the ribs are less elevated.

OCCURRENCE: Barril viejo shale. Barril viejo, Potrero de Menchaca, and Potrero de Oballos, Coahuila.

Class GASTROPODA

Genus *Turbo* Linné 1758

Turbo n. sp. aff. *mantelli* Leymerie

REMARKS: Five specimens from Locality A-34 in the Sierra de Mapimí, Durango, are too poorly preserved for illustration. They resemble *T. mantelli* Leymerie (1842, p. 13, pl. XVII, fig. 4; d'Orbigny, 1842-1843, p. 214, pl. 183, figs. 5-7) from the Neocomian of France but have a slightly wider apical angle, a more oblique aperture, and their main spiral ribs are narrower.

Turbo? gigas Imlay, n. sp.

(Plate 15, figures 1-4)

DESCRIPTION: The species is represented by three specimens of which the holotype retains much shell material on its last whorl but has a much corroded spire. The other two specimens are internal molds with fragments of shell material adhering and are about twice the size of the holotype.

Shell fairly large, turbinate, spire low, probably composed of four whorls; body whorl very large, forming about three-fourths of the total height, bluntly edged. Apparently nonumbilicated. Aperture probably ovate. Side of whorls of spire gently convex, shouldered on mold, bearing a nodose carina on shell. Body whorl ornamented with four prominent, diverging, nodose carinae of which the two most posterior are strong, and the most anterior is weak. The second carina from the posterior margin marks the most inflated part of the outer whorl. The tubercles are prominent, elongate spirally, and roughly arranged in vertical rows. The carinae are separated by somewhat broader, smooth interspaces. Dimensions of holotype: Altitude (incomplete) 39 mm.; maximum diameter 43 mm.

REMARKS: This species belongs to the genus *Turbo* in the broad sense although much larger than any Lower Cretaceous species of *Turbo* with which the writer is familiar. It possibly belongs in the subgenus *Sarmaticus* Gray 1847 whose known range is Upper Cretaceous to Recent (Wenz, 1938, p. 350-351).

TYPE: Holotype 20418, paratypes 20430, 20902, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Genus *Trochus* Linné 1758

Trochus n. sp. ind.

(Plate 19, figures 3, 4)

DESCRIPTION: One internal mold differs from any described species known to the writer. Shell large, regularly conical, apparently nonumbilicated. Apical angle about 55 degrees. Faces of whorls flat. Umbilical face concave, bordered by a sharp carina. Ornamentation of the whorl faces consists of four or five fairly strong spiral ribs and of stronger transverse ribs which incline at an angle of about 30 degrees to the spiral ribs. Transverse ribs number about 25 to 30 per whorl and terminate in tubercles along the umbilical border. Umbilical face ornamented with spiral striae.

SPECIMEN No. 20402, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Genus *Natica* Adanson 1777

Natica cf. *hugardiana* d'Orbigny

(Plate 14, figures 7, 8)

REMARKS: Five internal molds represent a species which greatly resembles *N. hugardiana* d'Orbigny (1842-1843, p. 151, pl. 171, fig. 2) in its short spire, depressed form, and wide umbilicus. The latter species occurs in the middle Neocomian deposits of Europe.

SPECIMEN No. 20775, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Natica cf. *neptuni* d'Orbigny

REMARKS: Two fragmentary molds from Barril viejo, Coahuila, have a spire of similar height to *N. neptuni* d'Orbigny (1850, p. 68; Cottreau, 1934, p. 12, pl. LXXI, figs. 1-4) and a little lower than *N. bulimoides* (Deshayes) (Leymerie, 1842, p. 12, pl. 16, fig. 9).

Genus *Tylostoma* Sharpe 1849

Tylostoma cf. *laharpi* Pictet et Campiche

REMARKS: One mold from Barril viejo, Coahuila, is compared with *T. laharpi* Pictet et Campiche (1862, p. 350, pl. LXXIII, figs. 1, 2) rather than with *Natica? praelonga* Deshayes (Leymerie, 1842, p. 13, pl. 16, fig. 8) because of the presence of narices.

Genus *Vermetus* Daudin

Vermetus? cornejoi Castillo y Aguilera *varians* Imlay, n. var.

(Plate 14, figures 2-6; Plate 15, figures 5-8)

1895. *Vermetus* (*Burtinella*) *cornejoi* Castillo y Aguilera, Bol. Com. Geol. Mex., No. 1, p. 12, Pl. VI, figs. 5, 6, and 7.

REMARKS: The Upper Jurassic and Neocomian deposits of the Mexican geosyncline contain locally an abundance of *Vermetus* which appear to belong to one long-ranging, highly variable species. The original specific description has been translated by Cragin (1905, p. 93). The Jurassic forms and some of the Neocomian forms in the University of Michigan collections agree in their characteristics with the original description, However, most of the Neocomian forms, which are represented by several hundred specimens, show considerable variation from the types. Among them about two-thirds are coiled dextrally instead of sinistrally; the whorls vary from nearly discoid to decidedly helicoid; the spiral carinae along the base of the tube are variably developed and become more prominent anteriorly; the upper part of the outer whorl tends to develop a shoulder; the growth lines become more pronounced anteriorly. The varietal name should include the Neocomian forms which show a tendency to develop a helicoid spiral and of which the majority are coiled dextrally.

TYPES OF VARIETY: Holotype 20617, paratypes 20615, 20616, 20618 to 20621, Museum of Paleontology, University of Michigan.

OCCURRENCE: Basal Cretaceous beds near Miquihuana, Tamaulipas; Carbonera formation at localities A-4, A-34, A-37, K-96, K-97 in eastern Durango; Barril viejo shale at Barril viejo and Potrero de Menchaca, Coahuila.

Genus *Nerinea* Defrance 1825

Nerinea sp. ind.

REMARKS: *Nerinea* is represented from Barril viejo, Coahuila, by several fragments of which one resembles *N. marcousana* d'Orbigny (Pictet et Campiche, 1862, p. 226, pl. LXIV, figs. 1, 2) from the Valanginian of Europe.

Genus *Harpagodes* Gill 1870

Harpagodes mexicanus Imlay, n. sp.
(Plate 14, figure 9)

DESCRIPTION: This species is represented by one compressed internal mold. Shell large, subfusiform; spire moderate in height, probably composed of four or five whorls, but only three whorls preserved, apical angle about 45 degrees; body whorl very large, forming about three-fifths of the total height. Side of whorls of spire gently convex; ornamented with a number of indistinct spiral ribs; suture moderately impressed. Body whorl ornamented with four prominent diverging carinae whose tips project forward and outward. Middle carinae largest. Carinae separated by broader, flat, smooth interspaces. Between the posterior carina and the suture are two weak spiral ribs. Anterior canal broken, finger-like, apparently not curved much posteriorly.

DIMENSIONS: Altitude (incomplete) 110 mm.; maximum diameter 95 mm.

REMARKS: This species resembles *H. jaccardi* (Pictet et Campiche) (1864, p. 557, pl. XCI, figs. 3, 4) from the Valanginian of Europe in the height of its spire and in its ornamentation but is much larger, apparently lacks small ribs between the carinae on the body whorl, and its anterior canal is not curved strongly posteriorly.

TYPE: Holotype 15976, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Harpagodes americanus Imlay, n. sp.
(Plate 15, figure 9)

DESCRIPTION: This species is represented by one internal mold. Shell large, subfusiform; spire short, probably composed of four whorls, but only two preserved, apical angle about 45 degrees; body whorl very large, forming about three-fourths of the total height. Side of whorls gently convex, suture moderately impressed. Posterior part of body whorl ornamented with many small spiral ribs separated by somewhat wider interspaces. Toward the anterior part of the body whorl four of these ribs develop into prominent, diverging carinae of which the two in the middle are the largest. The carinae are separated by broad, nearly flat interspaces which are marked by weak spiral ribs that increase in number anteriorly. Between the posterior carina and the suture are two spiral ribs of which the most posterior is much larger than the other and about one-third the size of the posterior carina. The anterior carinae curve anteriorly; the posterior carinae curve posteriorly; the posterior-most carina rests against the side of the spire. Anterior canal broken.

DIMENSIONS: Altitude (incomplete) 125 mm.; maximum diameter 110 mm.

REMARKS: This species may be distinguished from *H. mexicanus* Imlay by its shorter spire, relatively larger body chamber, and by the presence of minor ribs between the large carinae. It greatly resembles *H. desori* (Pictet et Campiche) (1864, p. 575, pl. XC, figs. 3, 4; d'Orbigny, 1842-1843, p. 304, pl. 212) from the Neocomian of Europe, but its carinae are broader and rounder.

TYPE: Holotype 20413, Museum of Paleontology, University of Michigan.
OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Class CEPHALOPODA

Genus *Phylloceras* Suess, 1854

Phylloceras cf. *serum* var. *perlobata* Sayn

(Plate 21, figures 19-21)

REMARKS: One small pyritized specimen probably belongs to the group of *Phylloceras tethys* (d'Orbigny) (1840-1841, p. 174, pl. 53, figs. 7-9; Gignoux, 1920, p. 90-94). No trace of ribs, constrictions, or swelling are visible, and the suture lines are poorly preserved. Its general form, somewhat flattened flanks, extremely narrow umbilicus, and marked enlargement of whorl height with growth, suggests a position near *P. serum* (Oppel) var. *perlobata* Sayn (1901, p. 7-9, pl. 1, figs. 6-8).

SPECIMEN No. 19039, Museum of Paleontology, University of Michigan.

OCCURRENCE: Taraises formation, lower part of upper member. Locality 58, Sierra de Parras, Coahuila.

Genus *Mexicanoceras* Imlay, 1938

Mexicanoceras laticostatum Imlay, n. sp.

(Plate 21, figures 17, 18)

DESCRIPTION: The species is represented by one pyritized specimen. Shell small; whorls semilunar in section, wider than high, embracing to the umbilical tubercles; flanks and venter evenly convex. Umbilicus narrow and deep, wall vertical near base, shoulder rounded. Body chamber unknown.

The upper part of the umbilical wall bears 15 faint ribs which terminate on the umbilical wall in low tubercles. From the tubercles pass bundles of three ribs of which one usually bifurcates low on the flank. The ribs are low, broadly rounded, and are separated by slightly wider interspaces. They incline forward on the lower part of the flank but cross the venter transversely. Exposed outer whorl marked by five weak constrictions.

Greatest diameter of holotype 20 mm.; width of umbilicus 4.8 mm.; height of last whorl 9.2 mm.; thickness of last whorl 12 mm.

REMARKS: This species most closely resembles *M. rarituberculatum* Imlay (1938a, p. 567, pl. 7, figs. 19-21) but may be distinguished by a broader whorl section, by fewer, broader, and lower ribs, and by the presence of constrictions.

TYPE: Holotype 19059, Museum of Paleontology, University of Michigan.

OCCURRENCE: Taraises formation, lower part of upper member. Locality 58, Sierra de Parras, Coahuila.

Mexicanoceras multicostatum Imlay, n. sp.

(Plate 21, figures 22-26)

DESCRIPTION: This species is represented by two pyritized specimens. The anterior end of the holotype has been slightly compressed.

Shell small; whorls semilunar in section, wider than high, embracing to the umbilical tubercles; flanks and venter evenly rounded. Umbilicus deep and narrow; wall vertical at base, steeply inclined above; shoulder rounded.

The upper part of the umbilical wall is marked by about 20 low, radially trending ribs which terminate on the umbilical shoulder in small tubercles that are elongated

and inclined forward. From the tubercles pass bundles of two or three ribs of which over half fork on the lower half of the flank. The ribs are moderate in height, narrowly rounded, and are separated by much wider interspaces. They incline forward rather strongly on the lower part of the flanks but recurve and cross the venter transversely. A faint thinning of the ribs along the midventral line occurs on the anterior end of the types. The outer whorl of the holotype bears four weak constrictions.

Greatest diameter of holotype 17.5 mm. (?); width of umbilicus 3 mm.; height of last whorl 8 mm. (?); thickness of last whorl 9.5 mm. (?).

REMARKS: This species differs from *M. gloriense* Imlay (1938a, p. 567, pl. 8, figs. 33-37) by its much finer and lower ribbing.

TYPES: Holotype 19063, paratype 18065, Museum of Paleontology, University of Michigan.

OCCURRENCE: Taraises formation, lower part of upper member. Locality 58, Sierra de Parras, Coahuila.

Genus *Maderia* Imlay, 1938

Maderia marcosensis Imlay, n. sp.

(Plate 21, figures 11-14, 27, 28)

DESCRIPTION: The species is represented by four pyritized specimens. Shell small; whorls semilunar in section, much wider than high, embracing to the umbilical tubercles; flanks rounding evenly from umbilical wall into broadly rounded venter. Umbilicus deep and fairly wide, funnel-shaped; wall high, vertical at base, steeply inclined above; shoulder rounded. Body chamber unknown.

Upper part of umbilical wall marked by about 25 low, radially trending ribs which terminate on the umbilical shoulder in low elongate tubercles. From the tubercles pass bundles of two, or less commonly three, ribs which incline forward on the flanks and then cross the venter transversely. In some bundles one rib branches low on the flank. The ribs are low, rounded, and are separated by slightly wider interspaces. No constrictions observed. A faint thinning of the ribs occurs along the midventral line. Suture line unknown.

Dimensions in mm. are as follows:

Specimen	Diameter	Whorl height	Whorl thickness	Umbilical width
Holotype 21158	24	11	15.5	6.1
Paratype 21157	18	8	12.5	5.3

REMARKS: This species is intermediate in appearance between *Maderia nontuberculata* Imlay (1938a, p. 560, pl. 8, figs. 1-4) and *Maderia semilunaris* Imlay (1938a, p. 561, pl. 3, figs. 6, 7, 13-15) but is readily distinguished from both by the common branching of the ribs in bundles of two instead of three. Furthermore it is distinguished from *M. semilunaris* Imlay by weaker and more numerous umbilical tubercles, a slightly narrower umbilicus, and a less abruptly rounded umbilical shoulder.

TYPE: Holotype 21158, paratype 21157, Museum of Paleontology, University of Michigan.

OCCURRENCE: Taraises formation, lower part of upper member. Locality 18, Sierra de Parras, Coahuila.

Maderia coahuilensis Imlay, n. sp.

(Plate 21, figures 15, 16)

DESCRIPTION: This species is represented by one pyritized specimen. Shell small; whorls semilunar in section, wider than high, embracing about three-fourths of preceding whorls; flanks rounding evenly into rounded venter. Umbilicus moderately deep and wide, funnel-shaped; wall vertical at base, steeply inclined above; shoulder rather abruptly rounded.

The upper two-thirds of the umbilical wall is marked by about 22 low, rounded ribs which become swollen on the umbilical shoulder and pass into pairs of ribs which incline forward low on the flanks and then cross the venter transversely. The flank ribs are fairly high, narrowly rounded, and are separated by much wider interspaces. The anterior end of the holotype shows a faint thinning of the ribs along the midventral line. No constrictions observed.

Greatest diameter of holotype 15 mm.; width of umbilicus 4.5 mm.; height of last whorl 5.7 mm. (?); thickness of last whorl 8 mm.

REMARKS: This species resembles *M. aguilerae* (Böse) (1923, p. 97, pl. 4, figs. 4-7) but has a wider umbilicus, fewer umbilical ribs, and stronger, more flexuous flank ribs.

TYPE: Holotype 12163, Museum of Paleontology, University of Michigan.

OCCURRENCE: Taraises formation, lower part of upper member. Locality 18, Sierra de Parras, Coahuila.

Maderia casitensis Imlay, n. sp.

(Plate 21, figures 29-31)

DESCRIPTION: This species is represented by one pyritized specimen. Shell small; whorls semilunar in section, much wider than high, embracing to the umbilical tubercle; venter broadly rounded. Umbilicus deep and wide, funnel-shaped; wall high, vertical at base, steeply inclined above; shoulder rather abruptly rounded. Body chamber unknown.

The upper part of the umbilical wall bears about 30 moderately low ribs which terminate on the shoulder in fairly acute tubercles. From the tubercles pass bundles of two or three ribs which incline forward slightly on the flanks but cross the venter transversely. In many bundles one of the ribs bifurcates on the flanks. The ribs are rounded, moderately low, and separated by slightly wider interspaces. Outer whorl bears one weak constriction. A slight thinning of the ribs along the midventral line occurs on the anterior part of the outer whorl.

Greatest diameter of holotype 27.3 mm.; width of umbilicus 8.7 mm.; height of last whorl 11.5 mm.; thickness of last whorl 20.5 mm.

REMARKS: This species is similar to *M. multituberculata* Imlay (1938a, p. 559, pl. 3, figs. 1-3) but has a more depressed whorl section, a wider umbilicus, more umbilical tubercles, and finer ribbing.

TYPE: Holotype 18060, Museum of Paleontology, University of Michigan.

OCCURRENCE: Taraises formation, lower part of upper member. Locality 58, Sierra de Parras, Coahuila.

Genus *Saynoceras* Munier-Chalmas, 1893

Saynoceras mexicanum Imlay, n. sp.

(Plate 21, figures 1-4)

DESCRIPTION: The species is represented by one crushed, pyritized specimen which does not show the body chamber.

Shell small, subglobose; whorl subcircular in section, slightly wider than high, embracing about one-half; flanks and venter evenly rounded. Umbilicus fairly narrow and deep; wall high, vertical at base, rounding evenly into flanks.

The sculpture of the outer whorl consists of ribs and of lateral and ventral tubercles which are extremely weak at the posterior end and extremely strong at the anterior end. About 17 narrow, fairly prominent ribs begin low on the umbilical wall and trend radially to lateral tubercles. From these tubercles pass broad low ribs which connect with ventral tubercles. The two rows of ventral tubercles are slightly offset in relation to each other and are connected across the midventral area by faint ribs which show a tendency toward a zigzag arrangement only at the posterior end of the whorl. The ventral tubercles have about the same strength as the lateral tubercles in early stages of growth but become nearly twice as strong in the later stages. The midventral area is broad at the posterior end of the outer whorl and becomes rather narrow at the anterior end. Suture line unknown. Approximate dimensions: Greatest diameter 18.5 mm.; width of umbilicus 3.5 mm. (?); height of last whorl 9 mm.; thickness of last whorl 10 mm.

REMARKS: This species differs from other described species of *Saynoceras* by its less globose form and coarser ornamentation. Its occurrence in beds of upper Barremian or lower Aptian age is interesting as the genus has hitherto been recorded by single species from the Tithonian (Roman, 1938, p. 391), the upper Valanginian (Fallot and Termier, 1923, p. 39-43), the lower Hauterivian (Imlay, 1938a, p. 552, 571), and the upper Albian (Pervinquière, 1907, p. 114).

TYPE: Holotype 17715, Museum of Paleontology, University of Michigan.

OCCURRENCE: La Peña formation, basal beds (Imlay, 1937b, p. 610 and 624) at locality 32, about 1⅔ miles south of Rancho El Angel, Sierra de Parras, Coahuila.

Genus *Oosterella* Kilian, 1911

Oosterella ? sp.

(Plate 21, figures 9, 10)

DESCRIPTION: One strongly compressed, calcareous fragment suggests the presence of the genus Oosterella in Mexico. Its venter bears a narrow, sharp keel which is bounded by faint lateral grooves. Its flanks are marked by broad, low, rounded, widely spaced, slightly flexuous ribs which terminate at the keel. The ribs are of two sizes. Some extend across the entire flank, and others begin near the middle of the flank. Some of the short ribs are faintly connected with the long ribs. All the ribs are faint and narrow at their dorsal extremities and are broadest and strongest at their ventral extremities.

REMARKS: The ornamentation suggests a comparison with *O. cultrata* (d'Orbigny) (1840-1841, p. 145, pl. 46, figs. 1-2) from the lower Hauterivian of France.

SPECIMEN NO.: 17701, Museum of Paleontology, University of Michigan.

OCCURRENCE: Taraises formation, upper part of upper member. Associated with *Olcostephanus* at Locality 42, Sierra de Parras, Coahuila.

Genus *Dichotomites* von Koenen, 1909

Dichotomites multicostatus Imlay, n. sp.

(Plate 18, figure 6)

DESCRIPTION: One fragment shows parts of two outer whorls of a large form. Whorl section higher than wide; outer whorl apparently embracing the inner only about

one-third; flanks high and somewhat flattened; venter rather broadly rounded; umbilical wall abruptly rounded.

The ribs on the umbilical wall are low, broad, and inclined backward. They terminate on the umbilical shoulder in small blunt tubercles or swellings which are slightly elongated radially. From each tubercle pass two ribs of which the most posterior bifurcates slightly above the zone of tubercles. A few simple ribs begin in weak swellings on the umbilical shoulder. Most of the ribs bifurcate again on the upper part of the flanks. The ribs are high, rounded, incline forward on the lower two-thirds of the flanks and then curve forward more strongly above the zone of secondary bifurcation. The interspaces are rounded and slightly wider than the ribs.

REMARKS: This species belongs in the genus *Dichotomites* on the basis of its small umbilical tubercles, the forward curve of its ribs on the upper part of the flanks and on the venter, and the character of its rib bifurcation. It is apparently less involute than is common in the genus, but this appearance is due in part to deformation. It greatly resembles *D. terscissus* (v. Koenen) (1902, p. 106, pl. LIII, figs. 1, 2) but has a broader whorl section and closer-spaced ribbing.

TYPE: Holotype 20439, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Genus *Acanthodiscus* Uhlig 1905 emend. Spath 1921

Acanthodiscus aff. *radiatus* Bruguière

(Plate 19, figure 2)

DESCRIPTION: Form stout, discoidal; outer whorl subhexagonal in section, slightly wider than high, embracing about two-fifths; lower part of flanks nearly flat, upper part rounding evenly into venter. Umbilicus fairly wide, wall nearly vertical, shoulder abruptly rounded. The primary ribs are strong, widely spaced, and bear prominent umbilical and lateral tubercles. From the latter pass bundles of two, or three, weak secondary ribs which incline forward and terminate ventrally in much weaker tubercles. Between most bundles is a single rib which begins at about the height of the lateral tubercle. The ventral area between the ventral tubercles is fairly narrow and is marked by weak rib continuations.

REMARKS: The specimen is similar in form and sculpture to *A. radiatus* Bruguière (Baumberger, 1906, p. 13-20, pls. 16-18 in part) but may be distinguished by weaker ventral tubercles and a narrower midventral area.

SPECIMEN NO.: 15978, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Acanthodiscus magnificus Imlay

(Plate 14, figure 1; Plate 18, figure 1)

1938. *Acanthodiscus magnificus* Imlay, Geol. Soc. Am., Bull., vol. 49, p. 572, pl. 9, figs. 1, 2, 7, 8; pl. 13, fig. 4; text figure 3.

REMARKS: This species is represented from Barril viejo by one internal mold which shows the major convolutions of the suture line. The latter, drawn at a whorl height of 45 mm., shows the characteristic pattern of *Acanthodiscus*. The lateral lobes consist of two unsymmetrical branches of which each is divided in turn. The first lateral lobe is moderate in width and much longer than the siphonal lobe. The second lateral lobe is much shorter than the first and trends obliquely to it. The external saddle is fairly broad and is divided by a secondary lobe into two

nearly equal parts. The first lateral saddle is narrower than the first lateral lobe, rather deeply incised, and subdivided by a long secondary lobe.

HYPOTYPE: 20395, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Genus *Leopoldia* K. Mayer 1887

Leopoldia truncata Imlay, n. sp.

(Plate 18, figures 2-4)

DESCRIPTION: This species is represented by one internal mold with some shell matter adhering near the umbilicus. Form discoidal, involute; outer whorl subtrapezoidal in section, nearly twice as high as wide, embracing almost completely; flanks fairly flat, lower two-thirds gently swollen; venter fairly narrow, truncated, slightly concave. Umbilicus shallow and extremely narrow, wall vertical, shoulder subangular.

Shell marked by faint, broad, falciform ribs which become fainter anteriorly. Ribs incline forward strongly on the upper third of the flanks and at the anterior end continue faintly across the venter.

The suture line (Pl. 18, fig. 3), drawn at a whorl height of 36 mm., is surprisingly undeveloped compared with other species of *Leopoldia* at similar diameters, and this condition does not appear to be due to corrosion. The broad unsymmetrical first lateral lobe, with the inner branch more strongly developed than the outer, is characteristic of the genus (Baumberger, 1906, p. 27).

Greatest diameter of holotype 67 mm.; width of umbilicus 4 mm.; height of last whorl 41 mm.; thickness of last whorl 22 mm.

REMARKS: This species is characterized by its extremely narrow umbilicus, truncated and slightly concave venter, and faint, broad ribbing.

TYPE: Holotype 15977, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale. Barril viejo, Coahuila.

Leopoldia crassicostata Imlay

(Plate 16, figures 1-3)

1938. *Leopoldia crassicostata* Imlay, Geol. Soc. Am., Bull., vol. 49, p. 582, pl. 11, figs. 7, 8.

REMARKS: This species is represented at Barril viejo by two specimens which show more advanced stages of growth than the Sierra de Parras specimens. They show that the whorls embrace about two-fifths and that the primary and secondary ribs became more loosely connected and less falciform during growth. The species is easily distinguished from other described Mexican species by its lower whorl section, lesser degree of involution, flatter venter, and coarser ribbing which remains fairly distinct until a late stage of growth. Among European species *L. dubisiensis* var. *bargemensis* Kilian (1915, p. 244, pl. XI, figs. 1, 2; pl. XII, fig. 5) probably bears the closest resemblance to *L. crassicostata* but may be distinguished by a thinner whorl section, a flatter venter, and apparently finer ornamentation. Roman (1933, p. 14, pl. 3, fig. 2) considers *L. bargemensis* a variety of *L. castellanensis* (d'Orbigny) and figures a form which is similar to *L. crassicostata* Imlay.

TYPE: Hypotypes 20793, 20422, Museum of Paleontology, University of Michigan.

OCCURRENCE: Taraises formation at Locality 58 in the Sierra de Parras; Barril viejo shale at Barril viejo, Coahuila.

Leopoldia spp.

(Plate 16, figure 4; Plate 17, figures 2, 3; Plate 19, figure 1)

REMARKS: The genus Leopoldia is represented in the near-shore facies at Barril viejo, Coahuila, by several specimens which probably represent the same species as occur (Imlay, 1938a, p. 581-583) in the Taraises formation. Two specimens are like *L. victoriensis* Imlay, and two like *L. bakeri* Imlay. One specimen (Pl. 16, fig. 4) is as large as some figured by Baumberger (1905, p. 26-47, pl. 4-9). A specimen (Pl. 17, figs. 2, 3) from the Potrero de Oballos near Hermanos, Coahuila, compares with *L. bakeri* Imlay in the closeness of ribbing at the posterior end of the exposed whorl.

FIGURED SPECIMENS: 15980, 20438, 20444, Museum of Paleontology, University of Michigan.

OCCURRENCE: Barril viejo shale, Barril viejo, Coahuila.

Genus *Thurmannites* Kilian, 1913

Thurmannites cf. *novihispanicus* Imlay

(Plate 17, figure 1)

REMARKS: One specimen bears a very close resemblance to *T. novihispanicus* Imlay (1937a, p. 563, pl. 78, figs. 8, 9; pl. 79, fig. 6) from beds of Valanginian age at Miquihuana, Tamaulipas. It possibly has a flatter venter and fewer single ribs. It is associated with *Exogyra reedi* Imlay, *Vermetus cornejoi* Castillo y Aguilera var. *varians* Imlay, *Berriasella?* sp., *Blanfordiceras?* sp., *Pinna* sp., *Spondylus* sp., and corals and represents the same horizon as Kellum's (1936, p. 1068) collection A-4 and A-34 in the mountains west of the Laguna district.

SPECIMEN NO.: 19415, Museum of Paleontology, University of Michigan.

OCCURRENCE: Carbonera formation, about 325 feet below top. Northwest end of Cuesta del Carbonera, about 2 miles south of Las Cuevas, Durango.

Genus *Distoloceras* Hyatt, 1900

Distoloceras sp. juv.

(Plate 21, figures 7, 8)

DESCRIPTION: One small specimen is particularly interesting because it illustrates the development of the ornamentation characteristic of the genus. It is possibly the immature form of *D. nodosum* Imlay. On the exposed outer whorl the ribs begin at the line of involution, are widely but variably spaced, and trend nearly radially across the flanks. At the posterior end the ribs are nearly equal in size and terminate ventrally in broad tubercles. Anteriorly they are differentiated markedly into prominent trituberculate ribs which terminate ventrally in large spines, and weak non-tuberculate ribs, which do not become stronger ventrally. Tuberculation appears first on the venter and last on the umbilical shoulder. The midventral area is narrow and slightly impressed.

SPECIMEN NO.: 19036, Museum of Paleontology, University of Michigan.

OCCURRENCE: Taraises formation, lower part of upper member. Locality 58, Sierra de Parras, Coahuila.

Genus *Hemihoplites* Spath, 1924

Hemihoplites? mexicanus Imlay, n. sp.

(Plate 21, figures 5, 6)

DESCRIPTION: The species is represented by a fairly mature form preserved as a calcareous cast and by a small pyritized whorl which has been slightly compressed. The larger specimen, here designated the holotype, was described previously (Imlay, 1938a, p. 586, pl. 2, fig. 10).

Shell discoidal, involute, whorl section subovate, higher than wide, thickest in lower third, probably slightly embracing preceding whorl; flanks gently convex, becoming flatter with age; venter rather narrowly rounded. Umbilicus fairly small; wall low, vertical at base, rounding evenly into flanks.

The shell is marked with flexuous, nontuberculate, widely spaced ribs which are weakest on the umbilical wall and strongest on the venter. The ribs trend nearly radially on the umbilical wall, incline forward strongly to the middle of the flanks, and then recurve to the venter which they cross transversely. Most ribs are single, but on the holotype a few appear to bifurcate low on the flank. In cross section the ribs are shaped like an inverted V, i. e., with broad bases and narrowly rounded summits. The interspaces are broadly rounded, becoming broader on outer whorls than on inner. Suture line unknown. Dimensions of paratype: Whorl height, 13.5 mm.; whorl thickness, 11.5 mm.(?).

REMARKS: This species probably belongs to an undescribed genus. Its ribbing suggests relationships with *Pascoeites* Spath (1933, p. 827, 828, pl. CXXVI, figs, 5a, b, 7a-c, 12a-c, pl. CXXVII, figs. 1a, b) and to *Aegocrioceras* Spath (1924, p. 76), but it is more involute, and its whorls enlarge more rapidly than either of these genera. It is more likely an immature form of the Hemihoplitidae, such as *Pseudothurmannia* Spath (1921, p. 66) or *Hemihoplites* Spath (1924, p. 84).

TYPE: Holotype 16866, paratype 19057, Museum of Paleontology, University of Michigan.

OCCURRENCE: Taraises formation, lower and upper parts of upper member. Localities 20 and 58, Sierra de Parras, Coahuila.

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EXPLANATION OF PLATES

PLATE 1

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

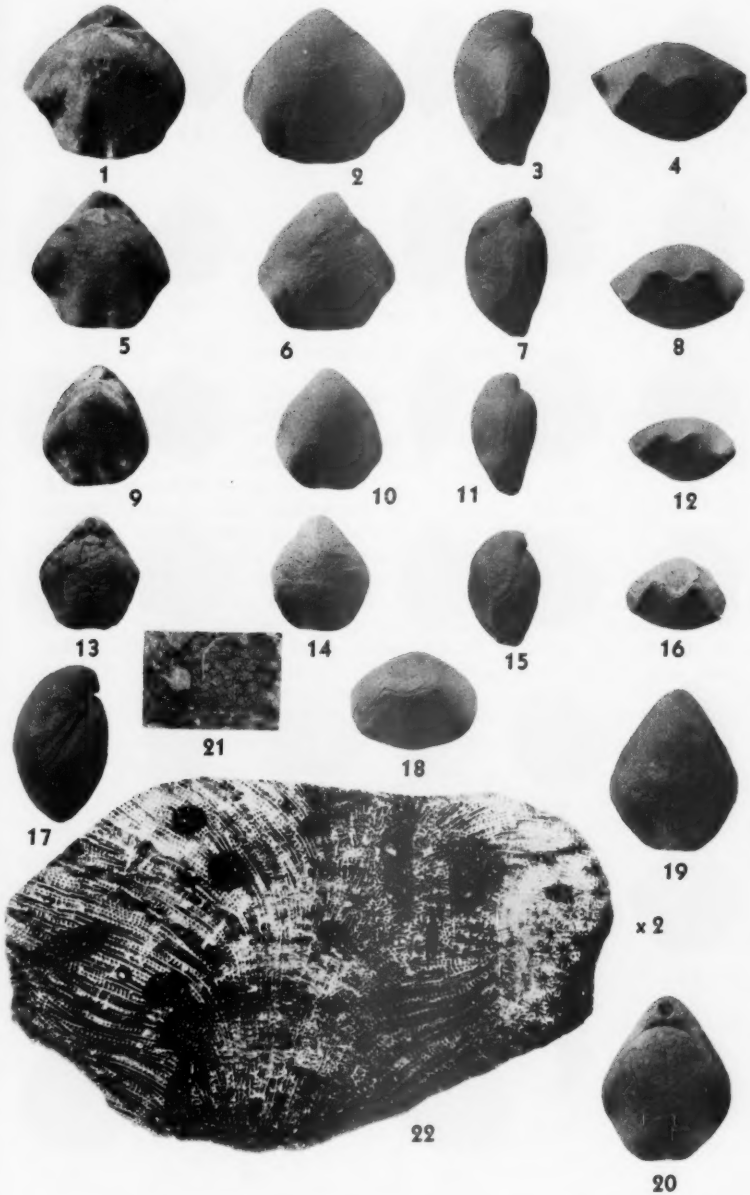
Figure

(1-16) *"Terebratula" coahuilensis* Imlay, n. sp.; (1-4) Dorsal, ventral, lateral, and anterior views of holotype U.M. 20926, Barril viejo shale, Barril viejo, Coahuila; (5-8) Paratype U.M. 20929, Barril viejo shale, Barril viejo, Coahuila; (9-12) Paratype U.M. 20927, Barril viejo shale, Sierra de Azul, Coahuila; (13-16) Paratype U.M. 20928, Barril viejo shale, Potrero de Oballos, Coahuila (p. 140).

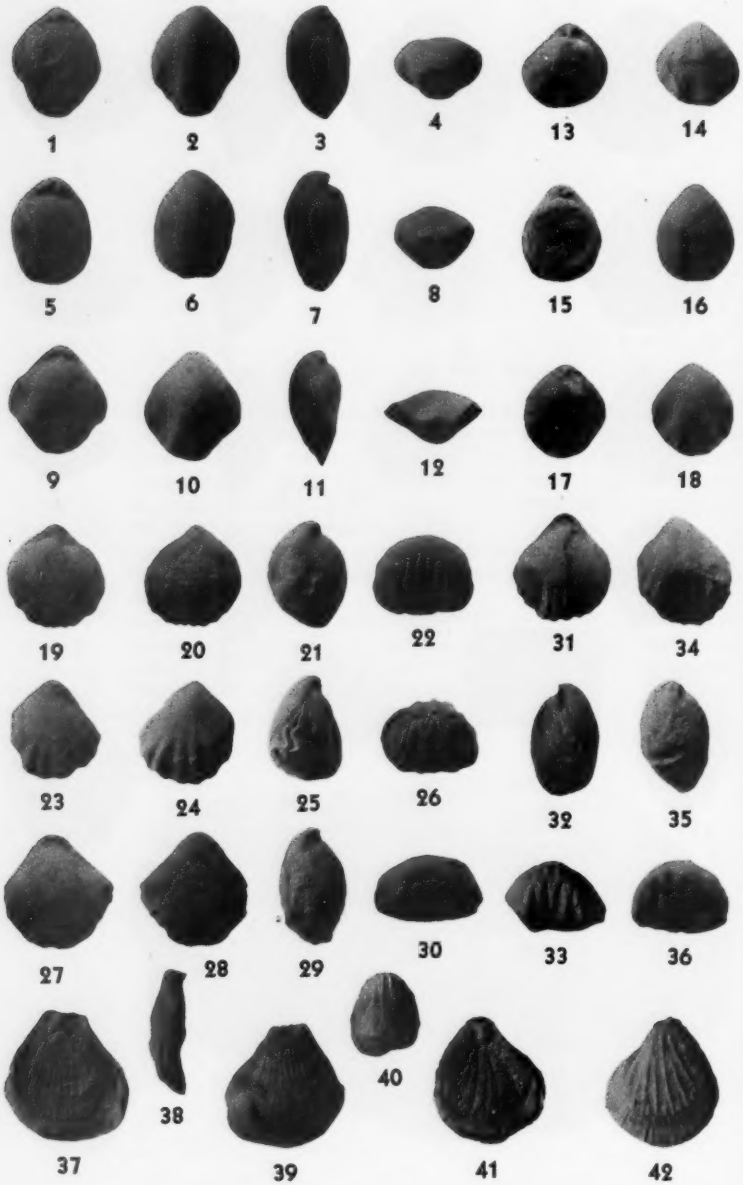
(17-20) *"Terebratula" kanei* Imlay, n. sp.; Lateral, anterior, ventral and dorsal views of holotype U.M. 20925, Barril viejo shale, Potrero de Oballos, Coahuila (p. 142).

(21, 22) *Astrocoenia hispaniensis* Imlay, n. sp.; (21) view of corallites of upper surface and (22) section of corallum of holotype U.M. 19345, Carbonera formation, northwest end of Cuesta del Carbonera, about 2 miles south of Las Cuevas, Durango (p. 136).

Figures natural size unless otherwise indicated.



NEOCOMIAN FOSSILS FROM NORTHERN MEXICO



NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

PLATE 2

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1-18) *Antiptychina? formosa* Imlay, n. sp.; (1-4) Paratype U.M. 20935; (5-8) Paratype U.M. 20933; (9-12) Holotype U.M. 20930; (13, 14) Paratype U.M. 20934; (15, 16) Paratype U.M. 20931; (17, 18) Paratype U.M. 20932. All specimens from Barril viejo shale; Sierra de Azul, Coahuila (p. 138).

(19-36) *"Rhynchonella" durangensis* Imlay, n. sp.; (19-22) Paratype U.M. 20939, locality A-4, eastern Durango; (23-26) Paratype U.M. 20944, locality A-34, eastern Durango; (27-30) Paratype U.M. 20946, locality A-4, eastern Durango; (31-33) Holotype U.M. 20947, locality K-96, eastern Durango; (34-36) Paratype U.M. 20945, locality A-4, eastern Durango. All specimens from Carbonera formation (p. 139).

(37-40) *Plicatula azulensis* Imlay, n. sp.; (37-39) Holotype U.M. 20942; (40) Paratype U.M. 20941. Both specimens from Barril viejo shale, Sierra de Azul, Coahuila (p. 145).

(41-42) *Plicatula torreonensis* Imlay, n. sp.; (41, 42) Holotype U.M. 15815, Carbonera formation, locality A-34, eastern Durango (p. 144).

All figures natural size.

PLATE 3

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

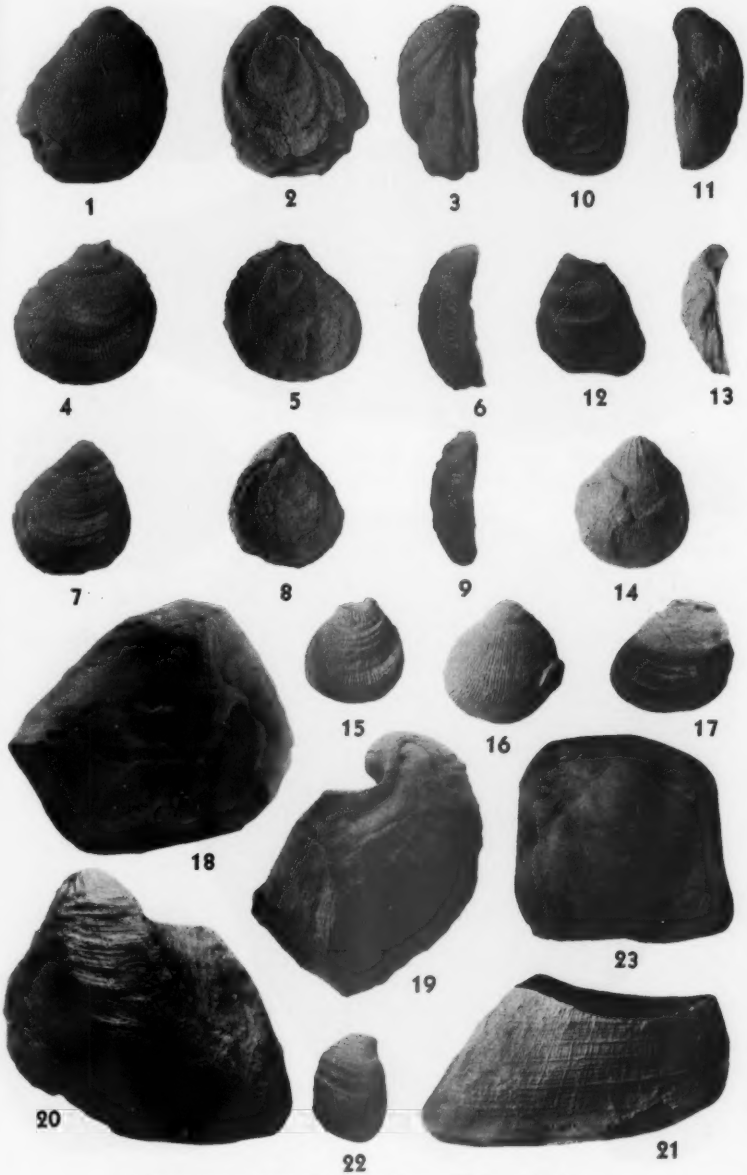
(1-9, 14-17) *Plicatula pulchra* Imlay, n. sp.; (1-3) Paratype U.M. 20608; (4-6) Paratype U.M. 20607; (7-9) Holotype U.M. 20606; (14) Paratype U.M. 20612; (15) Paratype U.M. 20610; (16) Paratype U.M. 15803; (17) Paratype U.M. 20611. All specimens from Carbonera formation, locality A-34, eastern Durango (p. 144).

(10-13, 22) *Plicatula umbonata* Imlay, n. sp.; (10, 11) Left valve and lateral view of paratype U.M. 20784; (12, 13) Left valve and lateral view of holotype U.M. 20787; (22) Paratype U.M. 20785. All specimens from Barril viejo shale, Barril viejo, eastern Coahuila (p. 145).

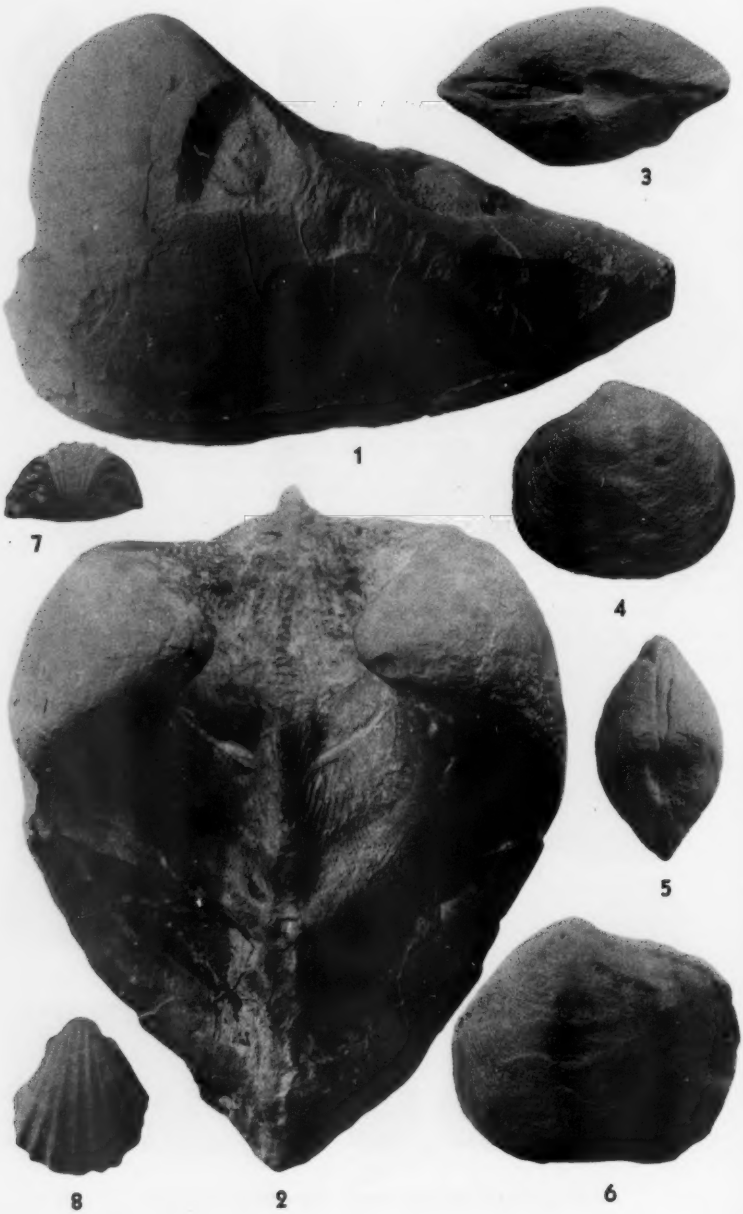
(18-21) *Cucullaea striatiumbonata* Imlay, n. sp.; Lateral, anterior, and dorsal views of holotype U.M. 20948, Carbonera formation, locality A-34, eastern Durango (p. 142).

(23) *Pecten (Camptonectes)* aff. *insutus* Cragin. Specimen U.M. 20949, Carbonera formation, locality A-34, eastern Durango (p. 146).

All figures natural size.



NEOCOMIAN FOSSILS FROM NORTHERN MEXICO



NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

PLATE 4

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1, 2) *Cucullaea gabrielis* var. *fraterna* Imlay, n. var.; Dorsal and lateral views of holotype U.M. 20728, Barril viejo shale, Barril viejo, eastern Coahuila (p. 143).

(3-6) *Lucina kellumi* Imlay, n. sp.; (3-6) Holotype U.M. 20730; (4, 5) Paratype U.M. 20431. Both specimens from Barril viejo shale, Barril viejo, eastern Coahuila (p. 153).

(7, 8) *Neithea biangulata* Imlay, n. sp.; Paratype U.M. 20731, Barril viejo shale, Barril viejo, eastern Coahuila (p. 146)

All figures natural size.

PLATE 5

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1, 2) *Prohinnites ordoñesi* Imlay, n. sp.; Lateral view and right valve of paratype U.M. 20390, Barril viejo shale, Barril viejo, eastern Coahuila (p. 147).

Figures about four-fifths natural size.

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

PLATE 6

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1) *Prohinnites ordoñesi* Imlay, n. sp.; Left valve of holotype U.M. 20442. Barril viejo shale, Potrero de Oballos, eastern Coahuila (p. 147).

(2-4) *Trapezium? diversicostulatum* Imlay, n. sp.; Anterior, dorsal and lateral views of holotype U.M. 15830, Carbonera formation, locality A-34, eastern Durango (p. 152).

(5, 6) *Trapezium? subtriangulum* Imlay, n. sp.; Dorsal and lateral views of holotype U.M. 20732, Carbonera formation, locality A-34, eastern Durango (p. 152).

(7, 8) *Panope* cf. *gurgitis* (Brongniart); Lateral view of specimen U.M. 20416, Barril viejo shale, Barril viejo, eastern Coahuila (p. 154).

Figures natural size unless otherwise indicated.

PLATE 7

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

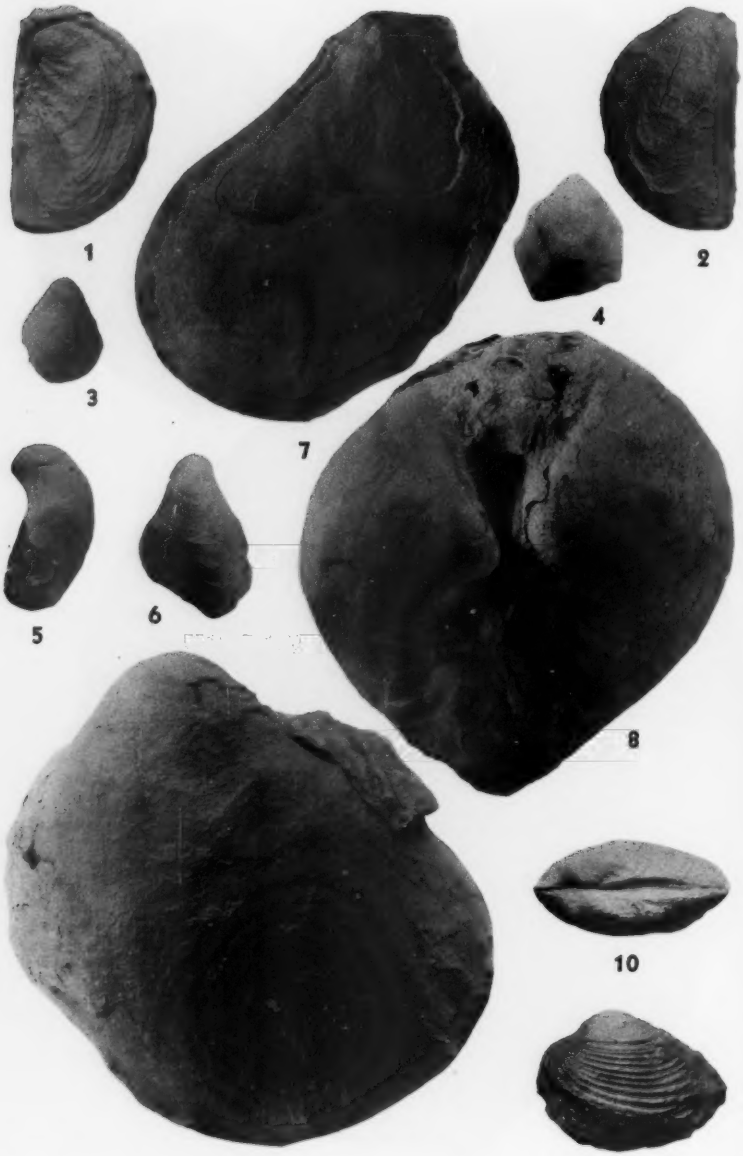
Figure

(1) *Prohinnites ordoñesi* Imlay, n. sp.; Right valve of holotype U.M. 20442, Barril viejo shale, Potrero de Oballos, eastern Coahuila (p. 147).

(2, 3) *Sphaera americanus* Imlay, n. sp.; Left valve and dorsal view of holotype U.M. 20421, Barril viejo shale, Barril viejo, eastern Coahuila (p. 153).

Figures natural size unless otherwise indicated.

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO



NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

PLATE 8

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1–6) *Gryphaea* spp.; (1, 2) Views of right and left valves of specimen U.M. 15826; (3) Left valve of specimen U.M. 15944; (4) Left valve of specimen U.M. 15810; (5, 6) Left valve of specimen U.M. 15805. All specimens from Carbonera formation, locality A-34, eastern Durango (p. 147).

(7) *Lima* (*Plagiostoma*) *kanei* Imlay, n. sp.; Left valve of Paratype U.M. 13848, Barril viejo shale, Barril viejo, eastern Coahuila (p. 150).

(8, 9) *Sphaera americanus* Imlay, n. sp.; Lateral and dorsal views of paratype U.M. 20445, Barril viejo shale, Potrero de Oballos, eastern Coahuila (p. 153).

(10, 11) *Astarte durangensis* Imlay, n. sp.; Dorsal and lateral views of holotype U.M. 15819, Carbonera formation, locality A-34, eastern Durango (p. 151).

All figures natural size.

PLATE 9

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1-3) *Lima* (*Plagiostoma*) *kanei* Imlay, n. sp.; (1) Left valve of holotype U.M. 20409, Barril viejo, Coahuila; (2) Right valve of paratype U.M. 13861, Potrero de Oballos, Coahuila; (3) Right valve of paratype U.M. 20427, Barril viejo, Coahuila. All specimens from Barril viejo shale (p. 150).

(4-6) *Exogyra reedi* Imlay; (4, 5) Hypotype U.M. 20567; (6) Hypotype U.M. 20568. Both specimens from Menchaca limestone, Potrero de Menchaca, eastern Coahuila (p. 148).

All figures natural size.

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

PLATE 10

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1, 2) *Gervillia alatior* Imlay, n. sp.; Left valve and anterior view of holotype U.M. 20625, Barril viejo shale, Barril viejo, Coahuila (p. 150).

Figures natural size.

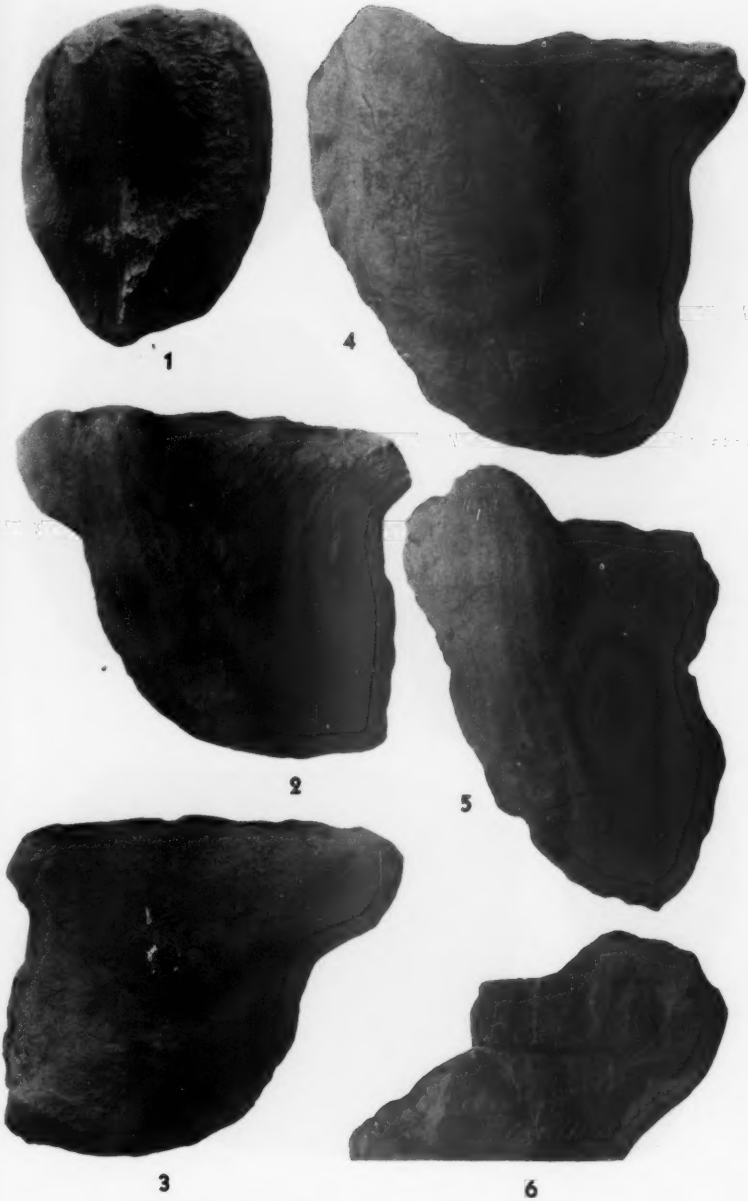
PLATE 11

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

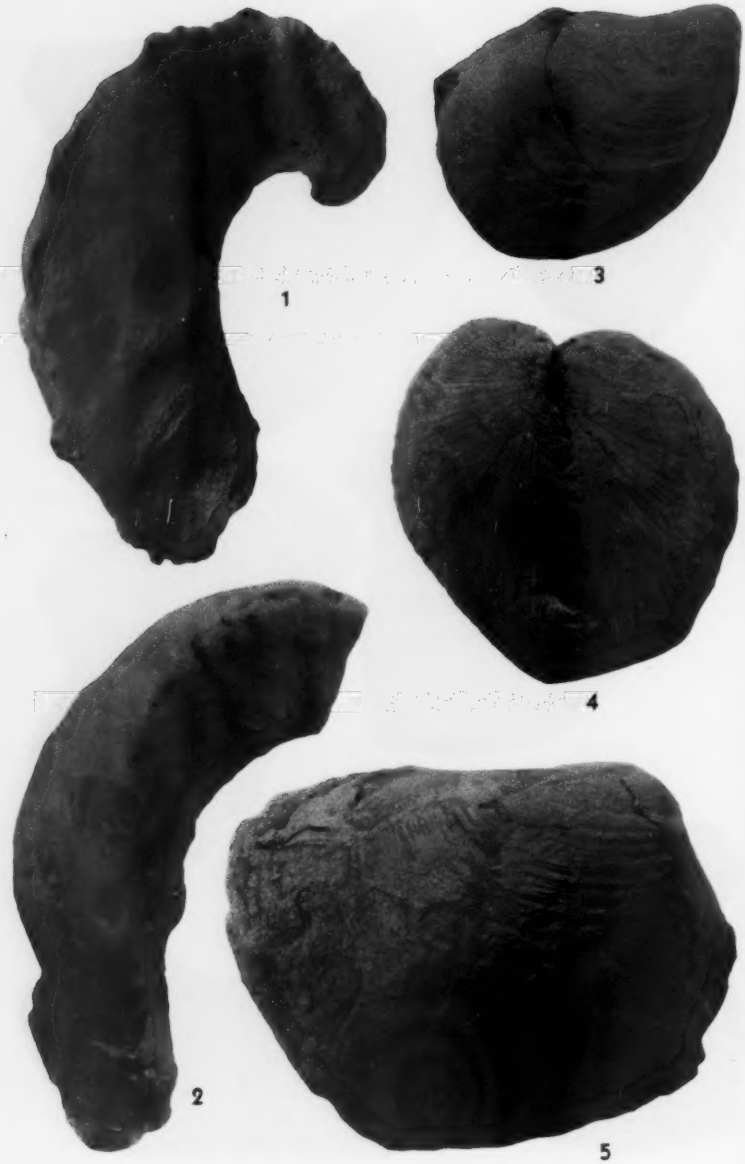
Figure

(1-6) *Gervillia alatior* Imlay, n. sp.; (1-3) Anterior and lateral views of paratype U. M. 20622; (4) Paratype U.M. 20377; (5) Paratype U.M. 20626; (6) Paratype U.M. 20624. Barril viejo shale, Barril viejo, eastern Coahuila (p. 150).

All figures natural size.



NEOCOMIAN FOSSILS FROM NORTHERN MEXICO



NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

PLATE 12

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1, 2) *Exogyra reedi* Imlay; (1) Posterior view of left valve of hypotype U.M. 15814 (*see* Pl. 13, figs. 4 and 5, for other views), Menchaca limestone, Potrero de Menchaca, Coahuila; (2) Left valve of hypotype U.M. 20393, Barril viejo shale, Barril viejo, Coahuila (p. 148).

(3-5) *Pholadomya* cf. *sanctae-crucis* Pictet and Campiche; (3) Right valve of specimen U.M. 20417; (4, 5) anterior and lateral views of specimen U.M. 15979. Both specimens from Barril viejo shale, Barril viejo, Coahuila (p. 155).

All figures natural size.

PLATE 13

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1-5) *Exogyra reedi* Imlay; (1) Hypotype U.M. 20453, Menchaca limestone, Potrero de Menchaca, Coahuila; (2, 3) Right and left valves of hypotype U.M. 20564, Carbonera formation, locality A-34, eastern Durango; (4, 5) Interior of left valve of hypotype U.M. 15814, Menchaca limestone, Potrero de Menchaca, Coahuila (p. 148).

All figures natural size.

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

PLATE 14

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1) *Acanthodiscus magnificus* Imlay; Suture line of hypotype U.M. 20395 shown on Plate 18, figure 1. Barril viejo shale, Barril viejo, Coahuila (p. 163).

(2-6) *Vermetus cornejoi* var. *varians* Imlay, n. var.; (2, 3) Paratype U.M. 20619; (4-6) Holotype U.M. 20617. Specimens from Carbonera formation, locality A-34, eastern Durango (p. 157).

(7, 8) *Natica* cf. *hugardiana* d'Orbigny; Specimen U.M. 20775, Barril viejo shale, Barril viejo, Coahuila (p. 157).

(9) *Harpagodes mexicanus* Imlay, n. sp.; Holotype U.M. 15976, Barril viejo shale, Barril viejo, Coahuila (p. 158).

All figures natural size.

PLATE 15

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

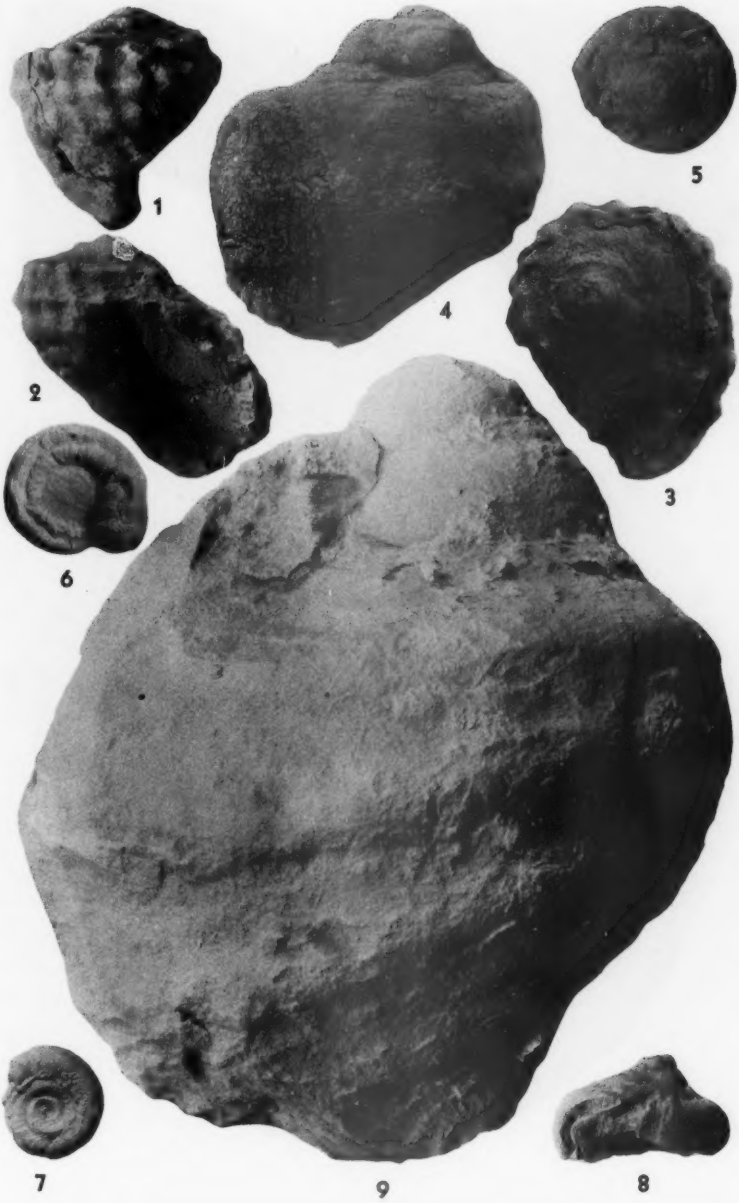
Figure

(1-4) *Turbo? gigas* Imlay, n. sp.; (1-3) views of holotype U.M. 20418; (4) Paratype U.M. 20902. Both specimens from the Barril viejo shale, Barril viejo, Coahuila (p. 156).

(5-8) *Vermetus cornejoi* var. *varians* Imlay, n. var.; (5, 8) Apical and apertural views of paratype U.M. 20620; (6) Basal view of paratype U.M. 20616; (7) Apical view of paratype U.M. 20621. Carbonera formation, locality A-34, eastern Durango (p. 157).

(9) *Harpagodes americanus* Imlay, n. sp.; Holotype U.M. 20413, Barril viejo shale, Barril viejo, Coahuila (p. 158).

All figures natural size.



NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

PLATE 16

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1-3) *Leopoldia crassicostata* Imlay; (1, 3) Lateral and ventral views of hypotype U.M. 20793; (2) Hypotype U.M. 20422. Both specimens from Barril viejo shale, Barril viejo, Coahuila (p. 164).

(4) *Leopoldia* sp., U.M. 15980, Barril viejo shale, Barril viejo, Coahuila (p. 165).

Figures natural size unless otherwise indicated.

PLATE 17

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

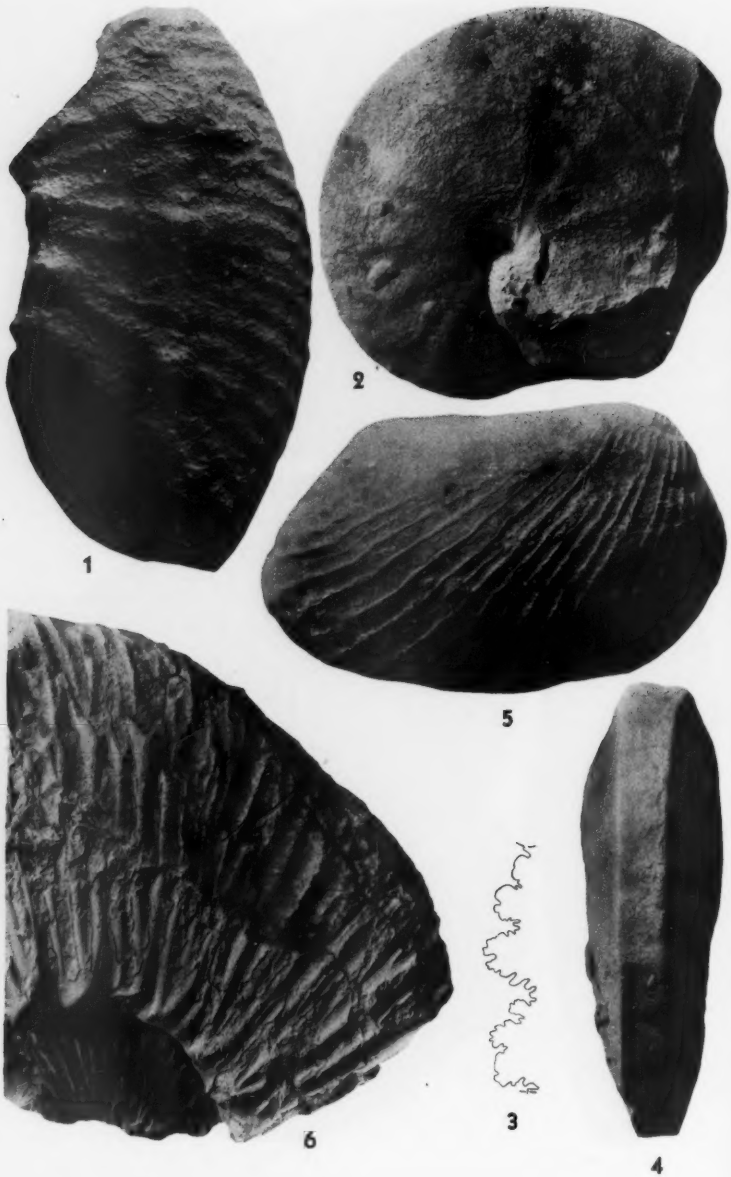
Figure

(1) *Thurmannites* cf. *novihispanicus* Imlay; Specimen U.M. 19415, Carbonera formation, northwest end of Cuesta del Carbonera, eastern Durango (p. 165).

(2, 3) *Leopoldia* cf. *bakeri* Imlay; Specimen U.M. 20444, Barril viejo shale, Potrero de Oballos, Coahuila (p. 165).

All figures natural size.

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO



NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

PLATE 18

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1) *Acanthodiscus magnificus* Imlay; Hypotype U.M. 20395, Barril viejo shale, Barril viejo, Coahuila (p. 163).

(2-4) *Leopoldia truncata* Imlay, n. sp.; Holotype U.M. 15977, Barril viejo shale, Barril viejo, Coahuila (p. 164).

(5) *Pholadomya* cf. *gigantea* (Sowerby); U.M. 19282, Barril viejo shale, Potrero de Oballos, Coahuila (p. 155).

(6) *Dichotomites multicostatus* Imlay, n. sp.; Holotype U.M. 20439, Barril viejo shale, Barril viejo, Coahuila (p. 162).

All figures natural size.

PLATE 19

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

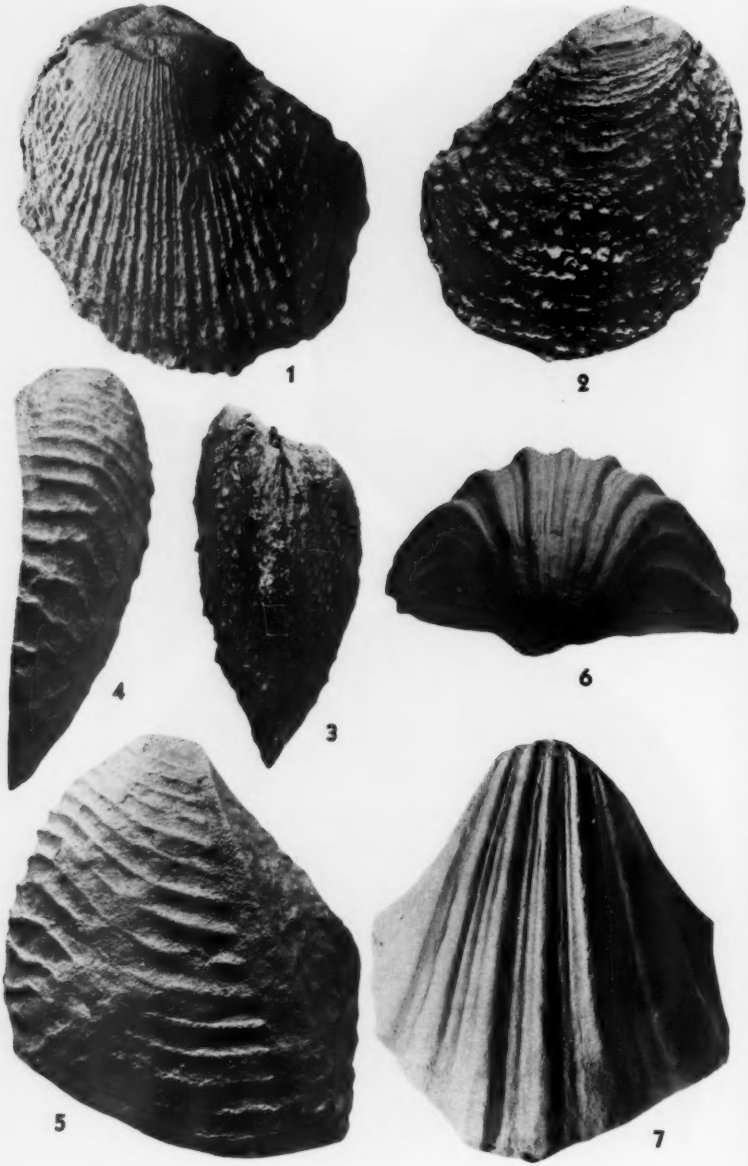
(1) *Leopoldia* sp.; U.M. 20438, Barril viejo shale, Barril viejo, Coahuila (p. 165).

(2) *Acanthodiscus* aff. *radiatus* Bruguière; Specimen U.M. 15978, Barril viejo shale, Barril viejo, Coahuila (p. 163).

(3, 4) *Trochus* n. sp. ind.; Specimen U.M. 20402, Barril viejo shale, Barril viejo, Coahuila (p. 156).

All figures natural size.

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO



NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

PLATE 20

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1-3) *Spondylus oballosensis* Imlay, n. sp.; Lateral and anterior views of holotype U.S. 21129, Barril viejo shale, Potrero de Oballos, Coahuila (p. 146).

(4, 5) *Trigonia* cf. *carinata* Agassiz; Specimen U.M. 21130, Barril viejo shale, Potrero de Oballos, Coahuila (p. 149).

(6, 7) *Neithea biangulata* Imlay, n. sp.; Holotype U.M. 19365, Barril viejo shale, Potrero de Menchaca, Coahuila (p. 146).

All figures natural size.

PLATE 21

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO

Figure

(1-4) *Saynoceras mexicanum* Imlay, n. sp.; Holotype U.M. 17715, La Peña formation, locality 32 (p. 161).

(5, 6) *Hemihoplites? mexicanus* Imlay, n. sp.; Paratype U.M. 19057, Taraises formation, locality 58 (p. 166).

(7, 8) *Distoloceras* sp. juv.; Lateral and ventral views of specimen U.M. 19036, Taraises formation, locality 58 (p. 165).

(9, 10) *Oosterella*? sp.; Lateral views of specimen U.M. 17701, Taraises formation, locality 42 (p. 162).

(11-14, 27, 28) *Maderia marcosensis* Imlay, n. sp.; (11-14) Paratype U.M. 21157; (27, 28) holotype U.M. 21158. Both specimens from Taraises formation, locality 18 (p. 160).

(15, 16) *Maderia coahuilensis* Imlay, n. sp.; Holotype U.M. 12163, Taraises formation, locality 18 (p. 161).

(17, 18) *Mexicanoceras laticostatum* Imlay, n. sp.; Holotype U.M. 19059, Taraises formation, locality 58 (p. 159).

(19-21) *Phylloceras* cf. *serum* (Oppel) var. *perlobata* Sayn. Specimen U.M. 19039, Taraises formation, locality 58 (p. 159).

(22-26) *Mexicanoceras multicostatum* Imlay, n. sp. (22) Paratype U.M. 18065; (23-26) holotype U.M. 19063. Both specimens from Taraises formation, locality 58 (p. 159).

(29-31) *Maderia casitensis* Imlay, n. sp.; Holotype U.M. 18060, Taraises formation, locality 58 (p. 161).

Localities listed above are in the Sierra de Parras, Coahuila.

All figures natural size.

NEOCOMIAN FOSSILS FROM NORTHERN MEXICO